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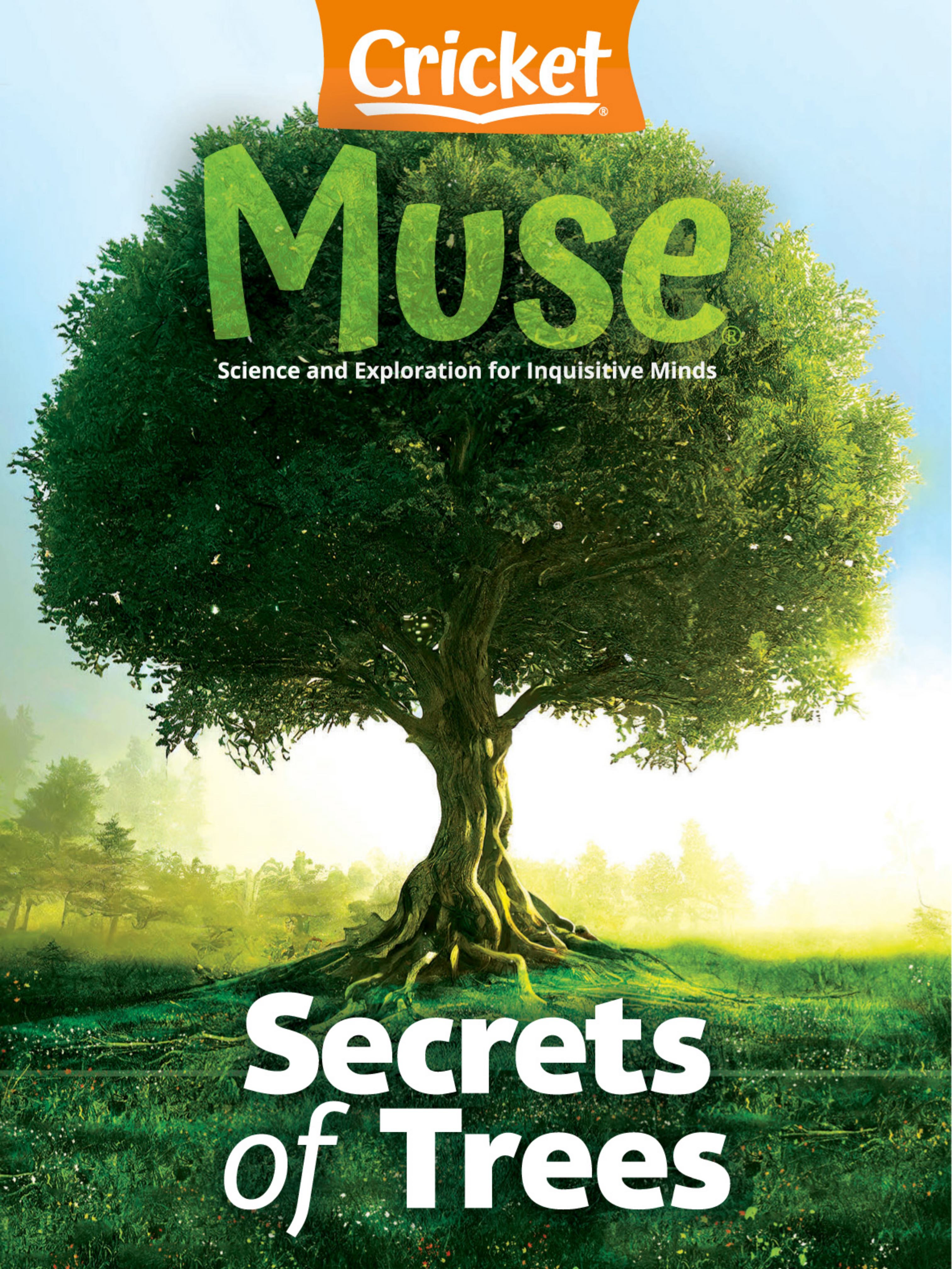

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LANZAROTE
Caliente.COM

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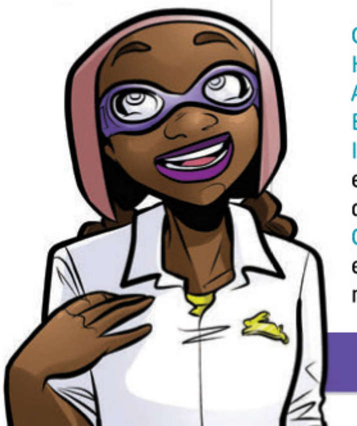

AARTI OKONKWO

CHILDHOOD FRIEND O
HEIGHT 5'5"
AGE 13
BORN San Francisco
INTERESTS Art and design, engineering, nano constructs, documentaries
ONCE SAID "I just experienced every conceivable version of myself!"

APRIL 2023
Volume 27, Issue #04

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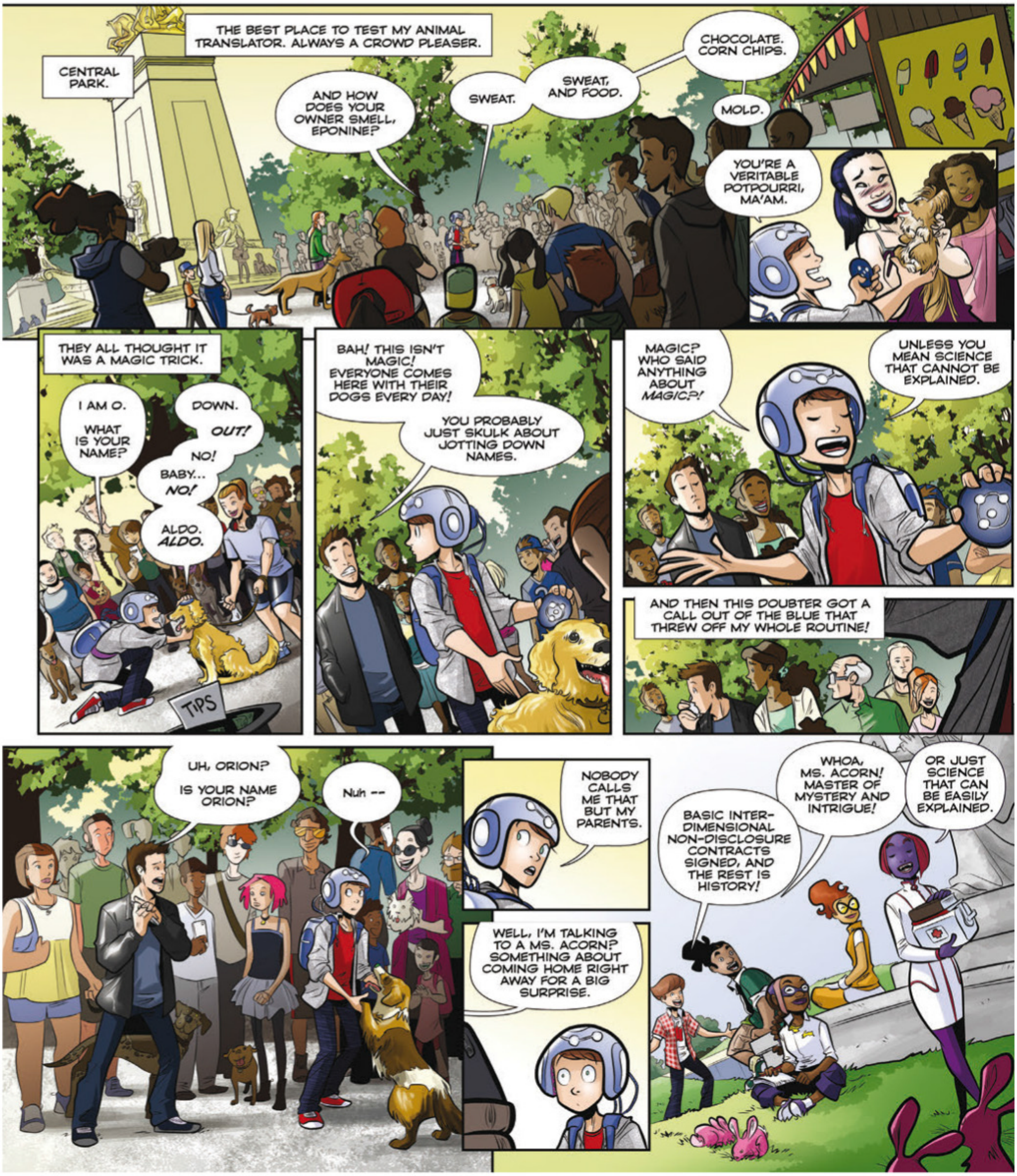
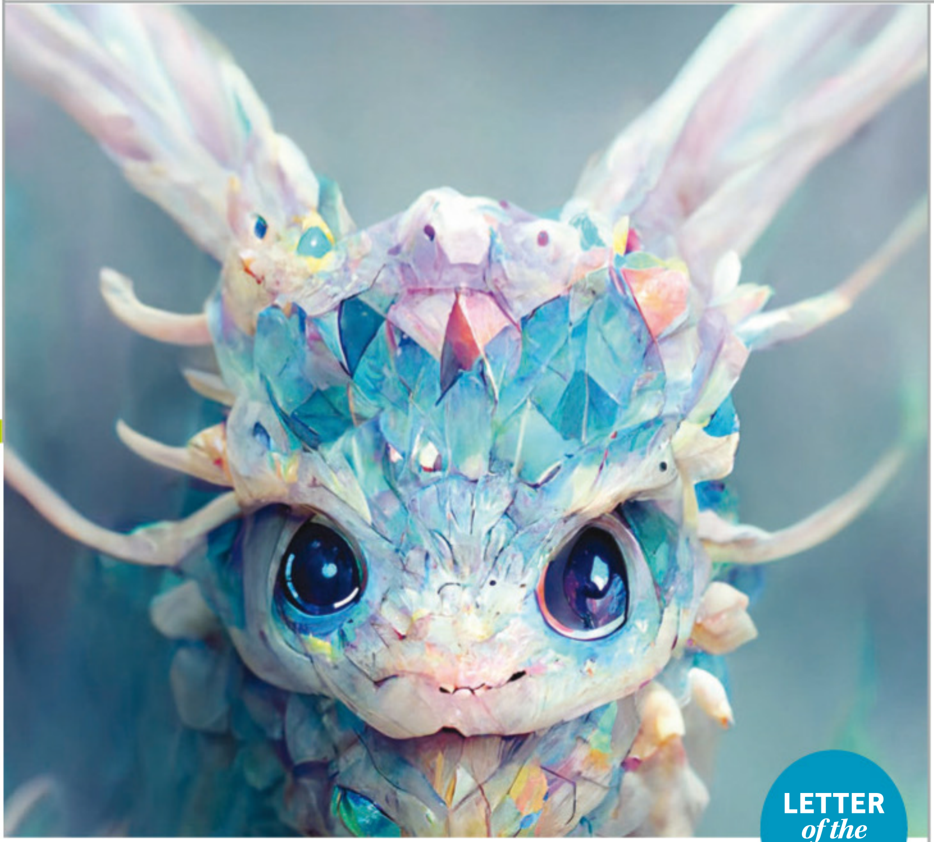

CENTRAL PARK.
THE BEST PLACE TO TEST MY ANIMAL TRANSLATOR. ALWAYS A CROWD PLEASER.
AND HOW DOES YOUR OWNER SMELL, EPONINE?
SWEAT.
SWEAT, AND FOOD.
CHOCOLATE. CORN CHIPS.
MOLD.
YOU'RE A VERITABLE POTPOURRI, MA'AM.
THEY ALL THOUGHT IT WAS A MAGIC TRICK.
I AM O. WHAT IS YOUR NAME?
DOWN. OUT! NO! BABY... NO!
ALDO. ALDO.
TIPS
BAH! THIS ISN'T MAGIC! EVERYONE COMES HERE WITH THEIR DOGS EVERY DAY!
YOU PROBABLY JUST SKULK ABOUT JOTTING DOWN NAMES.
MAGIC? WHO SAID ANYTHING ABOUT MAGIC?!
UNLESS YOU MEAN SCIENCE THAT CANNOT BE EXPLAINED.
AND THEN THIS DOUBTER GOT A CALL OUT OF THE BLUE THAT THREW OFF MY WHOLE ROUTINE!
UH, ORION? IS YOUR NAME ORION?
Nuh --
NOBODY CALLS ME THAT BUT MY PARENTS.
WELL, I'M TALKING TO A MS. ACORN? SOMETHING ABOUT COMING HOME RIGHT AWAY FOR A BIG SURPRISE.
BASIC INTER-DIMENSIONAL NON-DISCLOSURE CONTRACTS SIGNED, AND THE REST IS HISTORY!
WHOA, MS. ACORN! MASTER OF MYSTERY AND INTRIGUE!
OR JUST SCIENCE THAT CAN BE EASILY EXPLAINED.



LETTER *of the* MONTH

Crystal Court Correspondence

Hello! My name is Joiya. I am one of the five princesses of the Crystal Kingdom. I am a very new reader. I have been wanting to write to *Muse* ever since I got my first issue "Color Me Curious" in November/December 2021. My favorite issue is "Delicious!" (March 2022). I am a chef (and a princess). I was wondering, are Whatsi and Aarti related? And Ms. Acorn, who is your favorite? I was also wondering, are there more colors of bunnies? Can you do a more recent issue on climate change? And for Asian American Pacific Islander History Month, can you do an article about famous Asian Americans? If you put this in the FMP, I will send my head crystal dragon, and trust me, you don't want to meet her. If you publish this, I will send a baby crystal dragon. (Feed her rocks).

—JOIYA H / AGE 9 / PRINCESS / CRYSTAL KINGDOM

PS. The baby dragon may have very sudden growth spurts.

PPS. Did I mention I love to draw?

PPPS: Can you do an issue on conserving water? Cate, does time travel feel like a roller coaster?

Aarti and I often relate, like the other day when we both wanted extra curly fries at lunch.
—WHATSI

This Is No Illusion

I am a HUGE *Muse* fan and have been for a while. I absolutely love your scientific magazine content and am very fascinated in your new subjects each issue. My favorite one so far has been one of your newer ones, "The Way I See It" (January 2022). I love optical illusions and am very interested in the brain. I play a few different instruments and am hoping for a music-related article in one of your magazines. Music is one of my favorite things and I am ecstatic to learn as much as I can about it. Lastly, if this fan letter ends up in the dreaded FMP, I am seriously considering sending an army of IBLs (Ice Blue Lizards) to the creators. It is a new hybrid species I have discovered and have found that they look cute, but they are VICIOUS.

—MACY S. / AGE 11

PS. Aarti, are you related to Whatsi?

It's Electric! (Boogie Woogie Woogie)

Hi, I'm Isabelle, an almost sixth grader who's 10 years old. I'm writing because I would like you to do an article on how much electricity is used in a household of four each day. I think you should because I know my family uses a lot of electricity each day between the lights being left on or the microwave. My family has four people and one dog named Abner and one fish named Franklin. Please put this in your next magazine. Please!

—ISABELLE W / AGE 10 / WEST VIRGINIA

A Little Free Library beckons.

Look! A Book Nook!

Muse, your magazines are wonderful! I love _Muse_, (and _Cricket_—yeah, I get that one too!). Me and my mom have a lot of fun reading them and guessing the real or fake in "Muse News." I love reading and love writing even more. I think a good book can change a life! I wish reading were more accessible for kids, especially children in other countries. This means more tools for kids to learn to read and books that are easier to access.

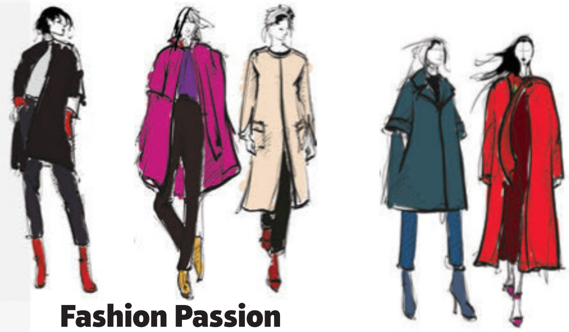
One of the best ways to make books easier to access for kids in your town is by setting up or donating to a Little Free Library. "What are those?" you might ask. They are tiny boxes somebody sets up in front of their house, and different people come to leave books and pick new books up! I think it's a great program for people to look into. That's enough of my blabbering for one letter, but before I go, I feel obliged to do what every *Muse* reader does and say that if you put this letter in the FMP, I will be extremely disappointed and send an army of my favorite book characters to destroy HQ. That includes every creature from The Chronicles of Narnia and the WHOLE Hogwarts gang. That's all for now!

—FRANCES MAY / AGE 12

Whale, Whale, Whale

Hello Musers! I wanted to write to you after reading the February 2022 article on the evolution of whales. I really enjoyed that magazine, but I did have one thing to say about the article. You left out one really cool detail about whale evolution from land mammals to sea: Whales today still have femurs! Modern whales have thigh bones just like ours that serve no purpose in their body, much like the human appendix. This is further evidence scientists have used to prove the theory that whales evolved from land mammals. I hope you learned something from this letter! Thanks!

-SAFIYA / AGE 13 / ISLAND OF CAT



Fashion Passion

I am 11 years old, and my name is Ruby. I live in a small town in the Upper Peninsula of Michigan, which is on Lake Superior. My dream is to be a designer of fashion, while using eco-friendly materials. I love *Muse*! I got it for a subscription in Christmas of 2019. My favorite issue is "Making Predictions" (July/August 2021). My favorite things and hobbies are:

•Drawing fashion and comics and cartoons

•Designing my bullet journal, the only way I stay organized

•Hanging out with my friends

I love *Muse* so much, and it would mean so much to me if you would put this in the letters section of your awesome magazine. Pretty please, don't put this in the FMP or I will send all the water in Lake Superior to destroy Muse Headquarters!

—RUBY P.

Galloping On

My name is Emerson, and I love *Muse*. I have been reading *Muse* since 2020, and it is awesome. Have you done an issue on exoplanets? If not, could you? I love learning about space so it would be awesome if you could do that. My sister would love an issue on horses. She loves them and so do I. We both take riding lessons.

Can Cate visit the future? Is the future awesome? What do you see in it? I ask a lot of questions, sorry. Should I be sorry? No, I should not be sorry. So, I am not sorry. I also love to find the fake story in the magazines. One more thing, why is O's name O?

-EMERSON C. / AGE 11

PS. How long has *Muse* existed? Is the fan mail pile a real thing?

I can visit the future and the past—including to January 1997, when Muse *was born. All time periods confirm that it is always good to ask many questions.*

—CATE

Hungry Hungry Ponies

I am an 11-year-old genius from planet Earth, and I LOVE *MUSE*!!!! I just want to say for starts, that there is a lot of things I love, so I'll just give you a brief list: cats, pencils, brainstorming, cuttlefish, the periodic table of elements, and much more, including *Muse*! I would LOVE, LOVE, LOVE it if you did a sequel to the fiction story "Frog Sleep." Also, I would like it if you did an article on the human brain and its intense complexity as well as hydraulics and where can find them. By the way, to any Musers reading this, I HAVE NOT READ *HARRY POTTER*. But, according to my friends, I'm a Hufflepuff. I would also like Muse HQ to know that I missed feeding ponies to write this letter. It's the third time I've written a letter AND if you don't publish this, I have no armies, just my sheer disappointment and heartbrokenness.

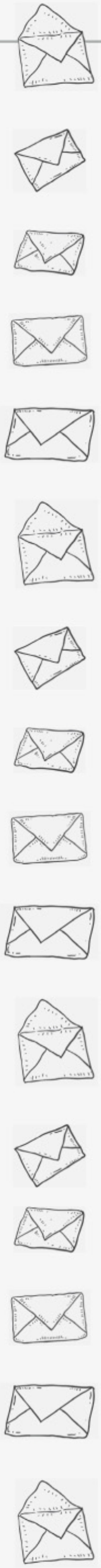
—LILY THE GENIUS / AGE 11 / GEORGIA, USA, EARTH

PS. By the time you publish this, I'll probably be 12.

PPS. Aarti is my favorite Muser.

I wonder what it would be like to cuddle a cuttlefish.

—AARTI



New Reader Notice

***Muse*, I love your magazine. I would love if you would make an issue on the history of books.** I personally would like to know who came up with the idea for graphic novels. I love books. And furthermore, I only started reading *Muse* a year ago, but I would like to know, what are HPBs and the FMP? Anyway, best regards.

—CORA / AGE 10 / RAVENCLAW AND FUTURE HEADMASTER OF HOGWARTS

HPB stands for Hot Pink Bunnies. No one knows their true nature, but they hop in and out quite often. And the Fan Mail Pit? I don't believe it exists.

—O

Something to say?
Send letters to Muse Mail,
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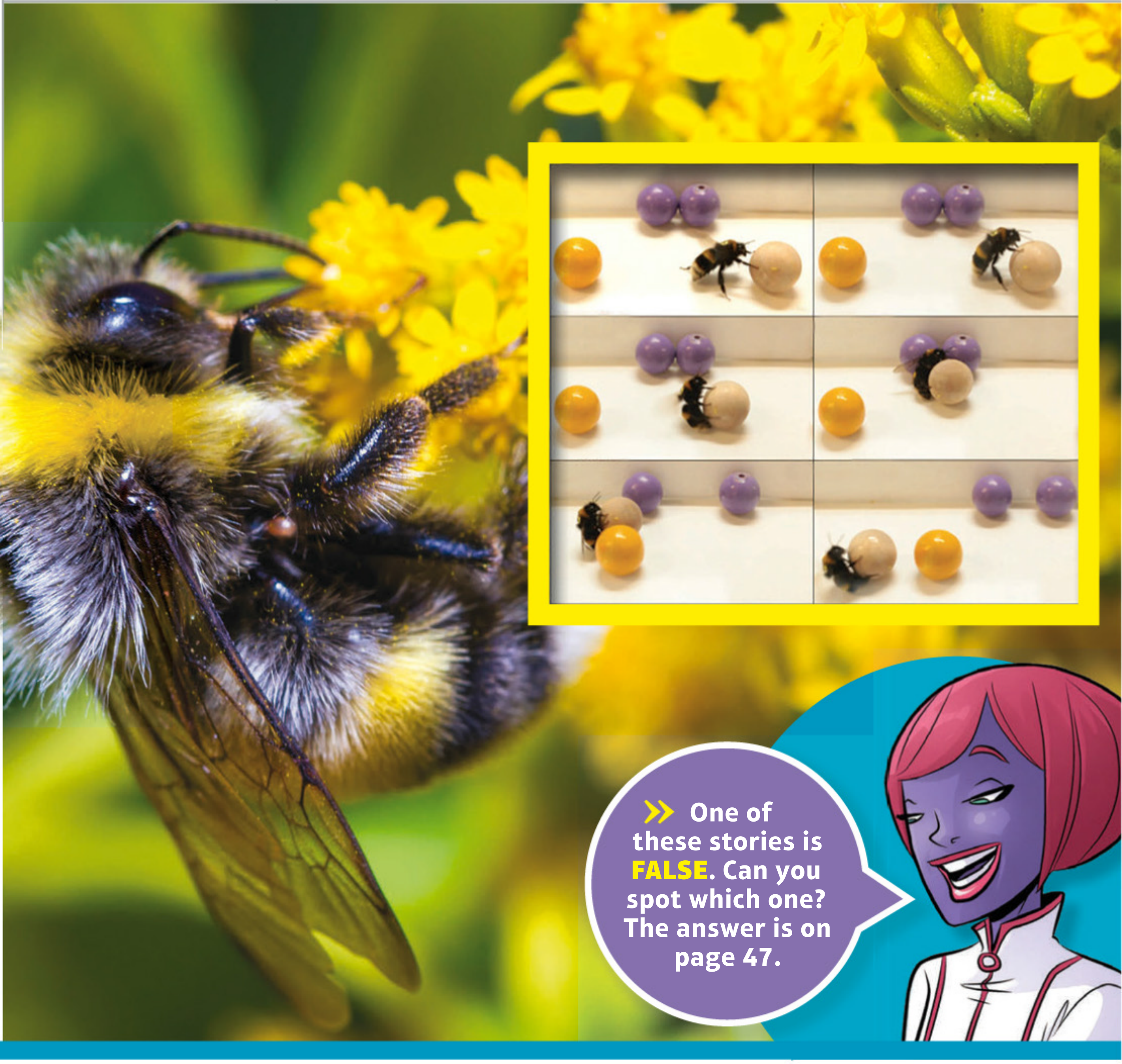
BY ELIZABETH PRESTON


» One of these stories is **FALSE**. Can you spot which one? The answer is on page 47.

text © 2023 by Elizabeth Preston

» **PLAY BALL!**

How Bees Have a Good Time

Bees have lots of impressive skills. They can work together. They can navigate between their home and the flowers they feed on. A few years ago, scientists even taught bumblebees how to use their feet to roll small, wooden balls.

In that experiment, the bees got a sugary reward for rolling the balls. But sometimes, the bumblebees rolled balls even without a sweet treat. The scientists wondered if rolling balls was just plain fun for the insects.

To find out, the scientists put bumblebees on a path with wooden balls on either side. The balls were about as big as marbles. There was no reason for the bees to move the balls around. But some bees left the path and started rolling the balls anyway. Younger bees and male bees were more likely than others to roll the balls.

The scientists think this shows that bumblebees can play. Many other animals are known to play, such as apes, dolphins, and birds. But finding playful behavior in a bug is a surprise.

» **ANIMAL BEHAVIOR**

Ape Friends

CHIMPANZEES AND GORILLAS CAN BE FRIENDS WITH ONE ANOTHER. That's what scientists found when they looked back at 20 years of observations from the Republic of Congo, in Africa.

Researchers had tracked individual chimpanzees and gorillas over time. Groups of gorillas and chimps sometimes overlap, like two friend groups sharing a playground. And when they do overlap, certain gorillas and chimps sometimes hang out, eat, or play together.

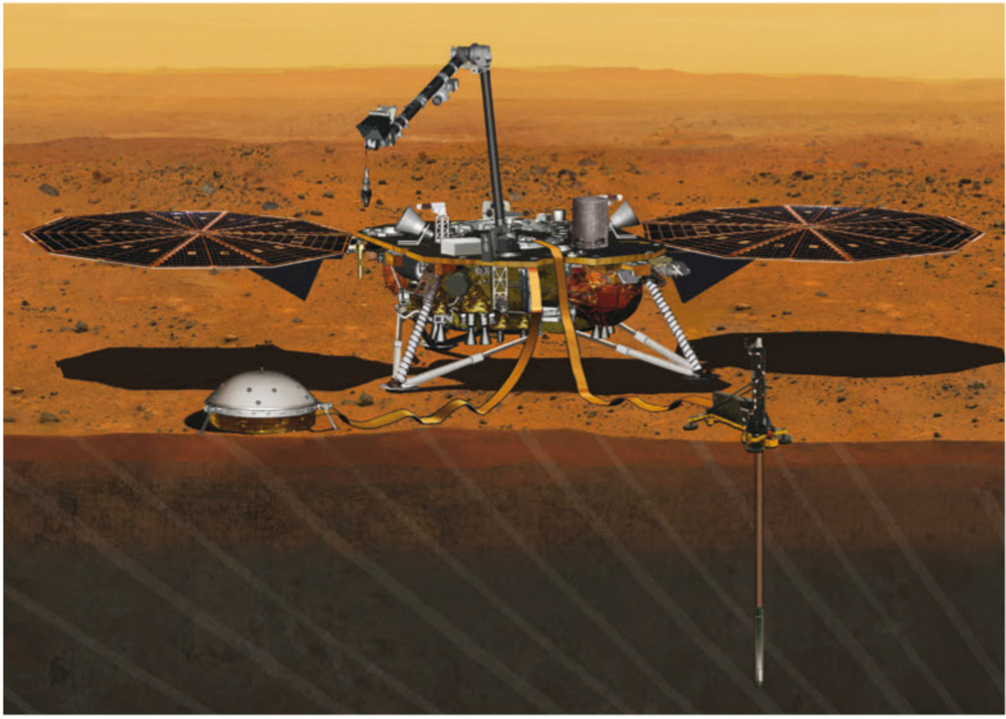
These apes may keep up their friendships for years. They don't mind that their hairy pals look different from them.

» **UP IN SPACE**

Measuring Marsquakes

NOT MUCH HAPPENS ON THE RED PLANET TODAY—OR SO WE THOUGHT. Mars had actively erupting volcanoes in its past. Now, scientists have found hints that there's still active magma rumbling under the planet's surface.

This information came from InSight, a robotic lander that's on the surface of Mars. Since arriving in 2018, InSight has recorded more than a thousand "marsquakes." Analyzing the data, planetary scientists found that the quakes likely came from hot magma moving deep underground. Not so boring, after all!



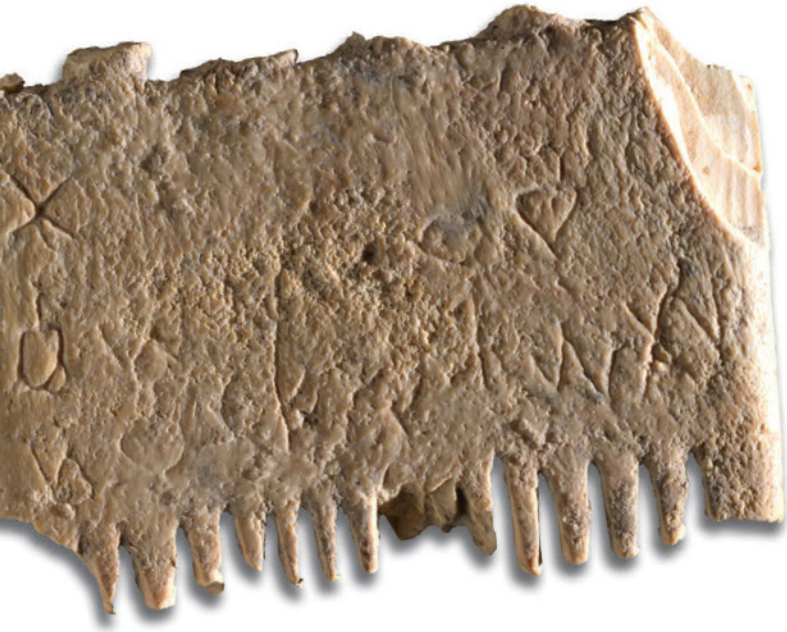
» SPA DAY

Why Did the Giant Rodent Get in the Bath?

CAPYBARAS ARE THE BIGGEST RODENTS IN THE WORLD. They're kind of like a large guinea pig that weighs as much as an adult human. In the wild, capybaras live in South America. But they're also popular in zoos in Japan.

Those zoos often let their capybaras hang out in hot springs. These are pools of water that are naturally warm and steamy, because of volcanic activity underground. The baths help the animals warm up in winter. But do capybaras really enjoy them?

To find out, researchers in Japan studied the facial expressions of capybaras sitting in hot springs. Based on how the animals squeezed their eyes shut in the bath, they seemed to be very comfortable. The scientists also studied the capybaras' skin. They saw that hot baths helped the giant rodents stay smooth and moisturized.



» ARCHAEOLOGY

This Ancient Comb Has Something to Say

WHEN ARCHAEOLOGISTS UNEARTHED THIS TINY COMB IN ISRAEL, SOME OF ITS TEETH WERE SNAPPED OFF. That wasn't surprising, since the comb was very old. It was carved from elephant tusk in about 1,700 BCE.

Years later, researchers noticed something else about the comb: There was a faint message scratched into the ivory. Translating the worn letters was slow and difficult. Finally, the full message was revealed: "May this tusk root out the lice of the hair and the beard."

No one is excited about lice. But the researchers were thrilled about this message. That's because its 17 letters came from the alphabet that eventually morphed into our own alphabet. In fact, this message about beard bugs is the oldest sentence in that alphabet that researchers have ever found. It's also a reminder that lice have been bothering humans since long before we had ways to write about it.

» TECH DESK

Ventriloquism for Dummies

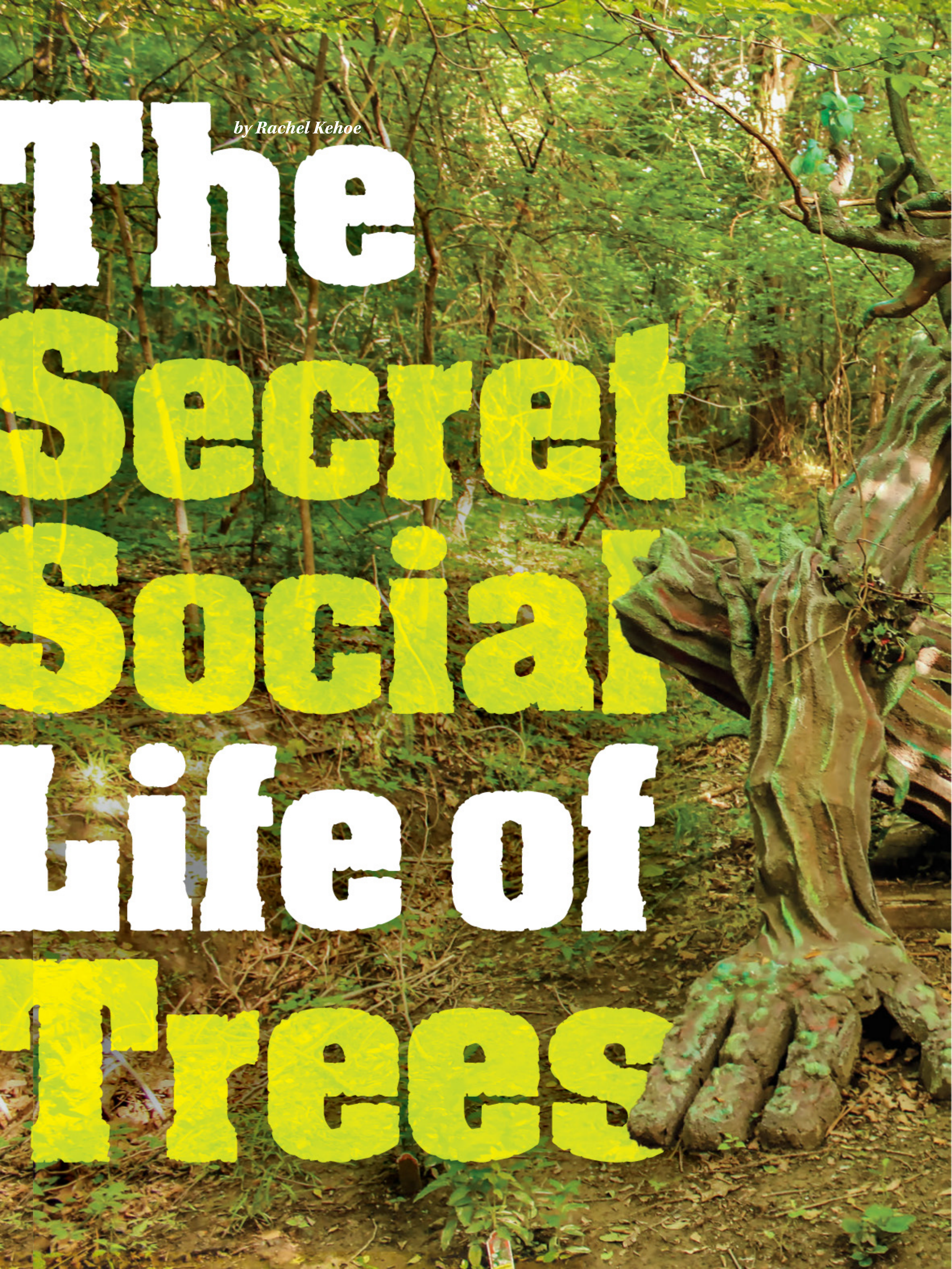
A PERFORMER—OFTEN A COMIC—WHO MAKES A PUPPET SEEM LIKE IT'S TALKING IS CALLED A VENTRILOQUIST. Ventriloquists appear to "throw their voices." Really, this is an illusion. Ventriloquists speak the puppet's lines without moving their own lips very much and the puppet's voice sounds different from their own. The audience imagines the puppet is talking instead.

Now, though, engineers are developing a tool that really can throw a person's voice.

The tool is designed for a person to wear against their throat, such as on a necklace. When the person talks, the device alters the sound waves so that they seem to be coming from someplace else. Depending on where their puppet is, the wearer can even choose whether to throw their voice to the right or left and vary its tone and pitch.

This means that someday soon, anybody could be a ventriloquist. Whether everyone will be funny remains an open question.

That's the news! Go to page 47 to see if you spotted the false story.



The Secret Social Life of Trees

by Rachel Kehoe

A hidden underground network allows trees to move nutrients and chemicals around. The question is why.

Trees may appear to be solitary beings. But they are more connected than it seems. Just beneath our feet lurks a complex underground network of fungi. Trees use this system to pass information, share food, and even wage war on their competitors. Ever-clever scientists have nicknamed this network the "wood wide web."

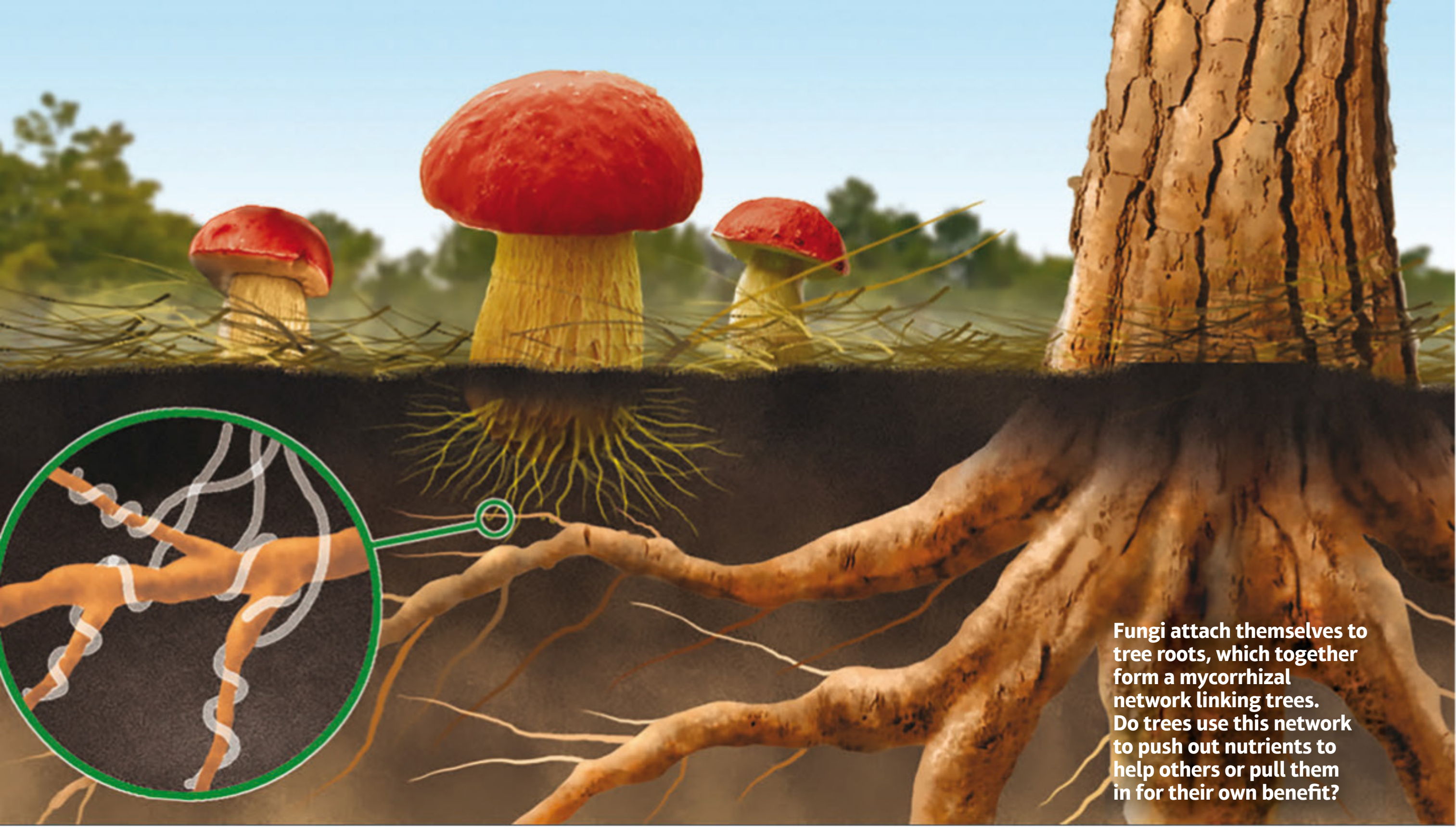
Underground Network

Every tree has underground roots that keep it anchored in the soil. Most of these roots are covered in a fuzzy, thread-like fungus that grow in and around tree roots. Together, the roots and fungi are called *mycorrhiza*. This mycorrhizal network spreads like a web, often connecting the roots of many neighboring trees and plants.

Trees and fungi rely on each other. The fungi provide trees with water and nutrients from the soil. In return, the fungi receive sugars from the tree. This relationship is called *mutualistic*—both organisms benefit. Trees with mycorrhizal fungi are healthier than those without. Mycorrhizal fungi also boost a tree's immune system and help forests thrive. Some scientists estimate that 90 percent of all plants have mycorrhizal fungi.

The Secret Language of Trees

For some time, mycorrhizae were believed to be simply an exchange of nutrients between fungus and plant. But in recent decades, scientists have discovered a deeper level of interaction. Mycorrhizae connect individual trees and let them transfer water, carbon, and other minerals.



Fungi attach themselves to tree roots, which together form a mycorrhizal network linking trees. Do trees use this network to push out nutrients to help others or pull them in for their own benefit?

Suzanne Simard was one of the first scientists to study fungal networks. She is a professor of forest ecology at the University of British Columbia in Canada. In one study, she shaded young saplings that were surrounded by older trees.

Limiting a tree's exposure to sunlight should have reduced its ability to do *photosynthesis.* That's the process by which plants and other organisms convert sunlight into energy. They produce energy in the form of carbon compounds, which may also be called sugars. A shaded tree shouldn't be able to get enough carbon. Instead, Simard discovered that the young trees' nutrient uptake increased. She concluded that the surrounding "mother" trees must be donating their carbon. As she sees it, trees are "super-cooperators" who use mycorrhizal networks to help each other out.

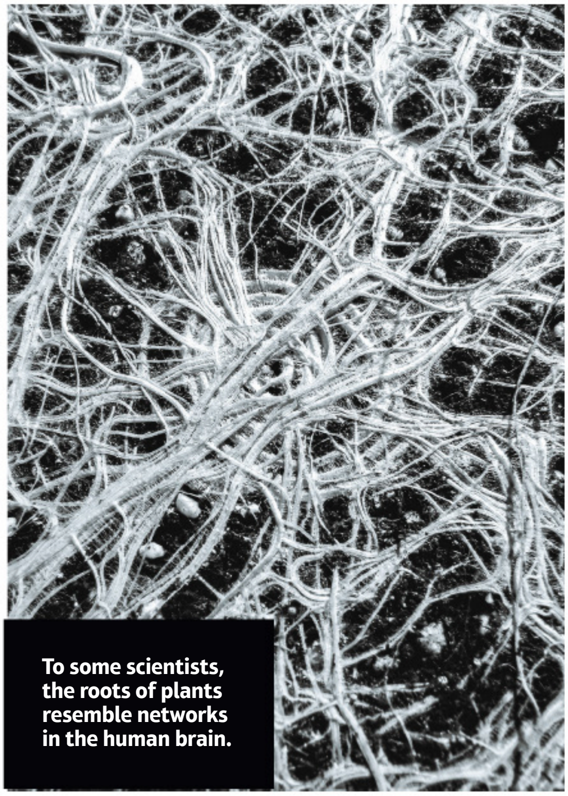
Friend or Foe?

As the idea of the "wood wide web" has taken root, some scientists have been skeptical. They argue that there is no evidence to suggest that trees cooperate with one another.

"It is nice to think of trees helping each other out," says Kathryn Morris. She is a biologist at Xavier University in Cincinnati, Ohio. Morris has spent years tapping into the secret social life of trees and plants. But she warns that these friendly exchanges may differ from what they seem. "A more likely explanation is that they use this network for individual gain," she says.

Life is not easy for forest trees. "Natural selection or 'survival of the fittest' plays a huge role in nature," she explains. To avoid being squeezed out, trees in a forest must succeed in the competition for limited resources such as water, nutrients, and sunlight. "In a forest, survival depends on which trees can stand their ground and obtain the resources they need," she says.

In this sense, Morris doesn't think trees *push* out nutrients to help others. Rather they *pull* them in for



To some scientists, the roots of plants resemble networks in the human brain.

A photo shows part of a tree mycorrhizal network created by fungi.

Some orchids hack the mycorrhizal network to take resources for themselves.

their own benefit. She says that it is unlikely that older trees are helping younger trees. Instead, the younger trees are probably mooching off the network "to steal nutrients for their own growth."

Hacking the 'Wood Wide Web'

Nature provides several examples of how plants use mycorrhizal networks to look out for number one. Some orchids hack the network to take resources made by other plants and trees. Most only do so for a short time, before they can produce their own food using photosynthesis. Some species of orchid, however, can't photosynthesize. They end up sponging nutrients off the system for their whole life.

There are also some tree species that release toxic chemicals into the network. One example is the black walnut. "This tree releases a chemical called juglone into the surrounding soil and mycorrhizal network," says Morris. "It harms the roots and stunts the growth of surrounding plants." This is called *allelopathy*, when the biochemicals of one organism damage another. "These chemicals are carried easily on the mycorrhizal network," says Morris. But she believes there may be other reasons for trees releasing toxic chemicals.

Black walnuts

Garlic mustard plants release toxic chemicals that help them survive cold winters but also harm nearby plants.

Morris has done a lot of work with garlic mustard plants. They also release toxic chemicals that harm surrounding species. But in this case, the chemicals also help increase garlic mustard's tolerance to the cold. Garlic mustard is one of the rare plants that can survive through cold winters. "We are discovering that many of these toxic chemicals often have a dual purpose," she says.

Morris also points out that some trees produce toxic chemicals to stop certain insects from feeding on them. "In this case, the toxic chemicals ward off pests," she says. "But they also happen to limit the growth of surrounding plants." Morris suspects the trees continue to make these chemicals even after the threat diminishes because they happen to reduce competition with other plant species.

Complex Connections

The discovery of mycorrhizal networks has led to questions about whether trees in a network should be considered a single superorganism. "It depends on context," says Morris. If a caterpillar is munching on a tree, that tree will release chemicals through the fungal network that alert others to the threat. "In this instance, it makes sense to think of the entire system as interconnected because we see this type of signaling," she says.

Giraffe vs. acacia tree

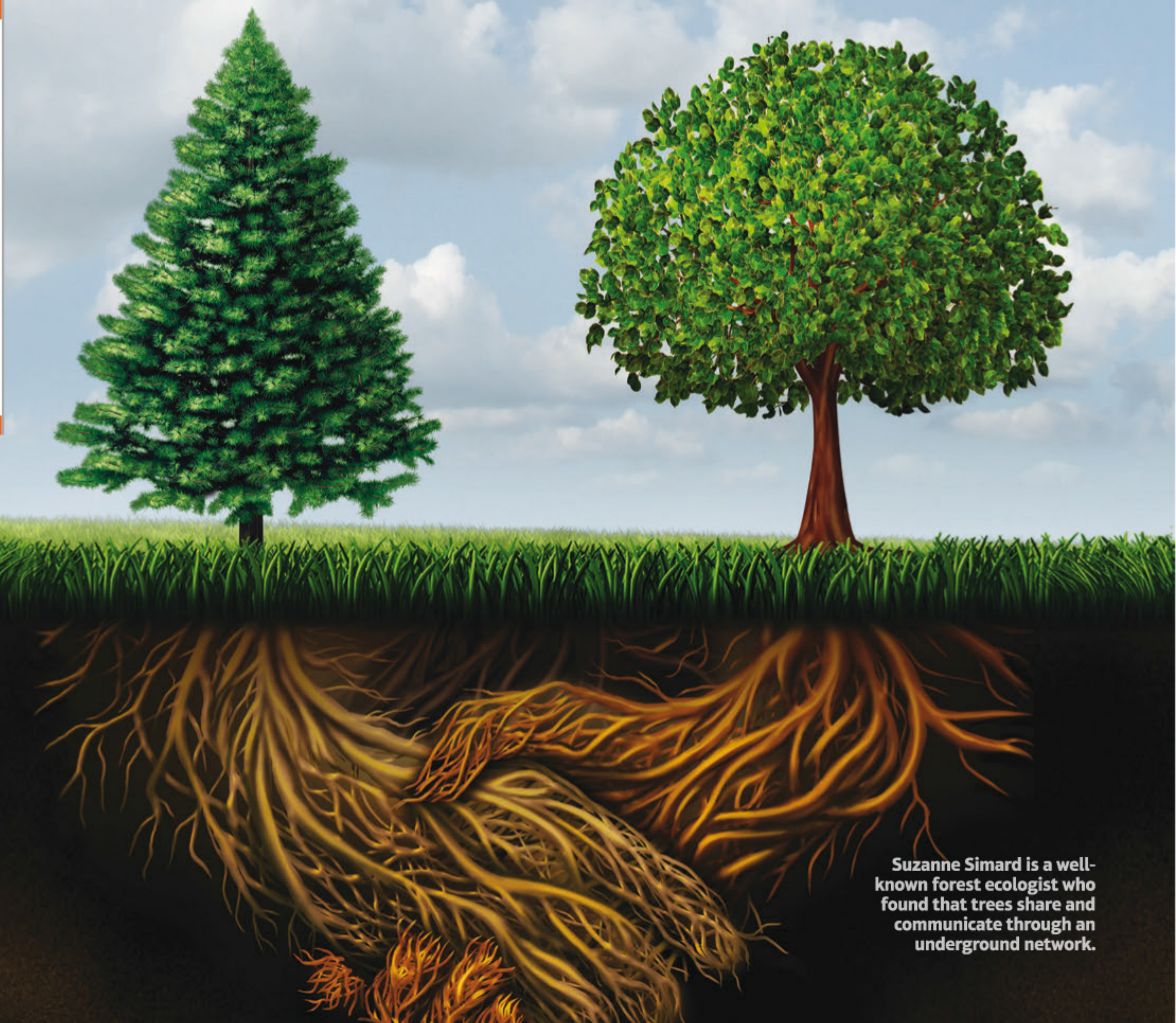
ACTIVATING THE ACACIA TREE ALARM

Acacia trees emit a chemical called ethylene gas when grazing giraffes chew on them. This distress signal can be detected by surrounding trees up to 55 yards (50 meters) away. It prompts them to start moving tannins to their own leaves. Tannins create a bitter taste in the mouth. They make unripe fruits and seeds taste unpleasant. When eaten in large quantities, tannins can even sicken or kill large herbivores.

This would deter most animals. But the giraffe has learned how to outsmart this early warning system. When munching on an acacia, giraffes will typically graze upwind to avoid the bitter leaves from trees who have already received the distress signal. They only spend a few minutes at each tree. Another trick they use is to move to a tree further away where it can't sense the release of ethylene gas.

Scientists are just beginning to understand the secret social life of trees. But one thing appears certain. In many forests, mycorrhizal networks connect trees and move around nutrients and chemicals. So, the next time you're out in the forest, you might like to imagine the hidden interactions taking place right beneath your feet.

Rachel Kehoe is a nonfiction writer from Burlington, Ontario. It might be an exaggeration to call tree signals a language. But she still likes to wonder if we will ever see the Language of Trees on Google Translate.



Suzanne Simard is a well-known forest ecologist who found that trees share and communicate through an underground network.

by Jeanne Panek

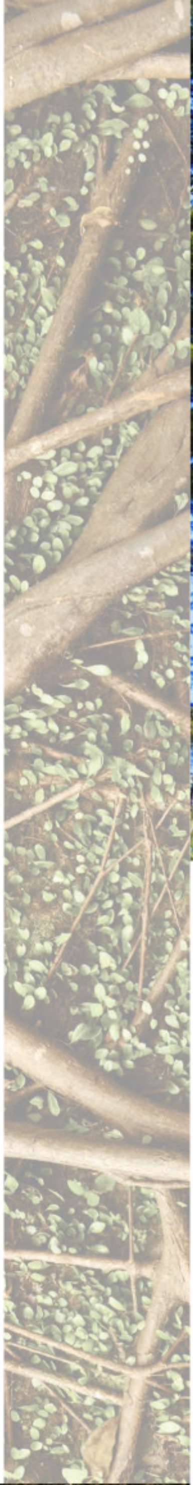
SUZANNE SIMARD

FOREST ECOLOGIST

Most people look at a forest and see trees reaching for the sky. Suzanne Simard sees trees holding hands underground. Simard is a well-known *forest ecologist*—a scientist studying forest patterns and relationships. She works at the University of British Columbia in Canada and is the author of the bestselling book *Finding the Mother Tree.*

With her research, Simard has followed tree roots to an astounding new possible discovery, that trees share and communicate through an underground network. Her science inspired the Tree of Souls in the movie *Avatar* and has forever changed the way we think about forests.

FINDING THE MOTHER TREE
Discovering the Wisdom of the Forest
SUZANNE SIMARD

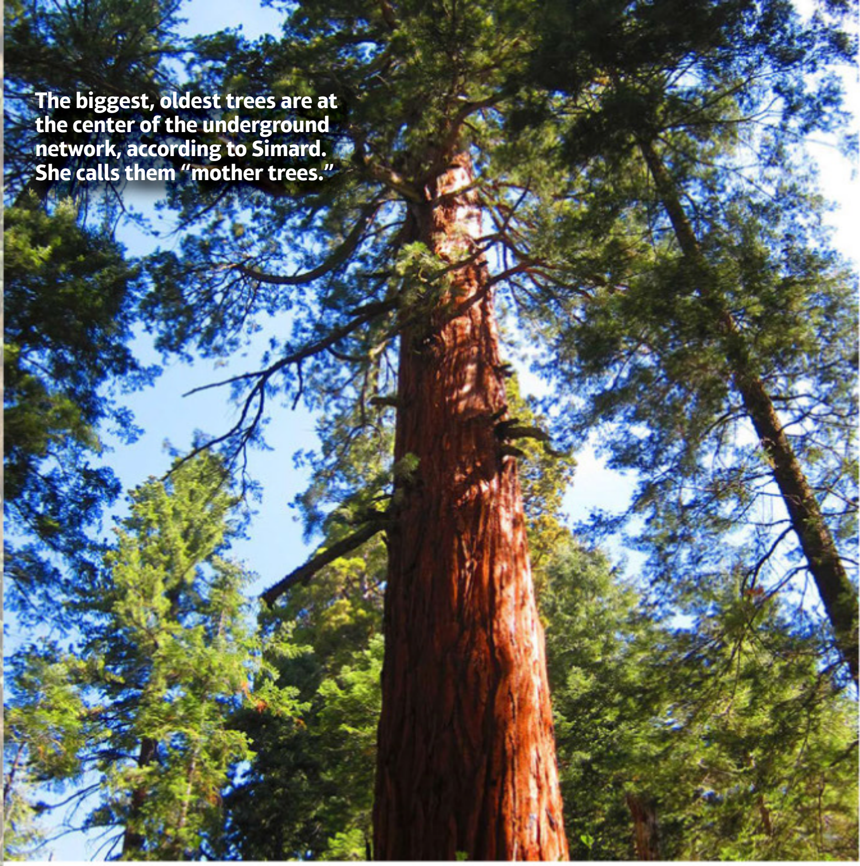


CAN YOU TAKE US ON A WALK-THROUGH A FAVORITE FOREST?

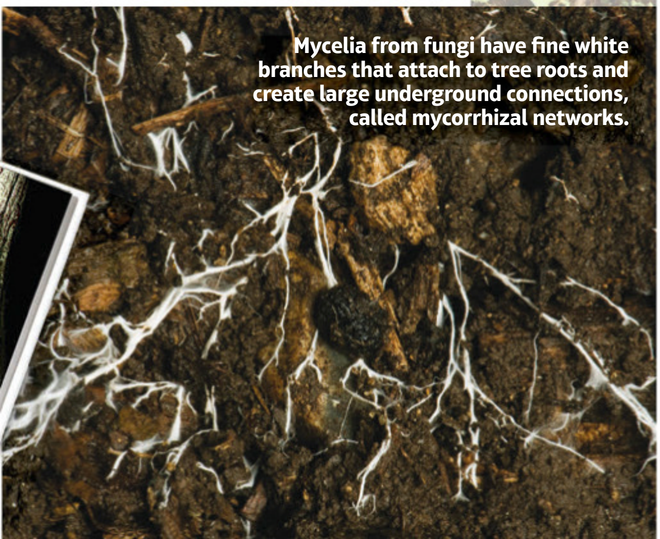
When you walk through a forest, usually you follow a trail. But if you get off the trail, you end up in a much wilder place, with soft mosses and scratchy bushes. Listen for an owl. Watch a deer bounding by. Then, sit with the trees. They're all shapes and sizes. Some are hundreds of years old. But you might see trees your age, too, with their moms, dads, and grandparents all around you. When you feel the connection to these trees as your own family, you are suddenly part of the forest.

YOU DISCOVERED SOMETHING REMARKABLE ABOUT THE FOREST.

My research is about exploring the below ground world. As a kid, I loved playing in dirt, even eating it. I love everything about soil. All kinds of teeny organisms live underground, creating the soil food web. It's made up of billions of creatures including a group of fungi called *mycorrhizae*, attached to tree roots. Mycorrhizae [*mike-o-RISE-ay*] literally means "fungus-root." We've known these fungi and roots depend on each other. Mycorrhizae collect soil nutrients for trees. In exchange, the trees give them carbon sugars they've made through *photosynthesis*. [Photosynthesis is the process that plants and other organisms use to convert sunlight, water, and CO2 into sugars.]



The biggest, oldest trees are at the center of the underground network, according to Simard. She calls them "mother trees."



Mycelia from fungi have fine white branches that attach to tree roots and create large underground connections, called mycorrhizal networks.

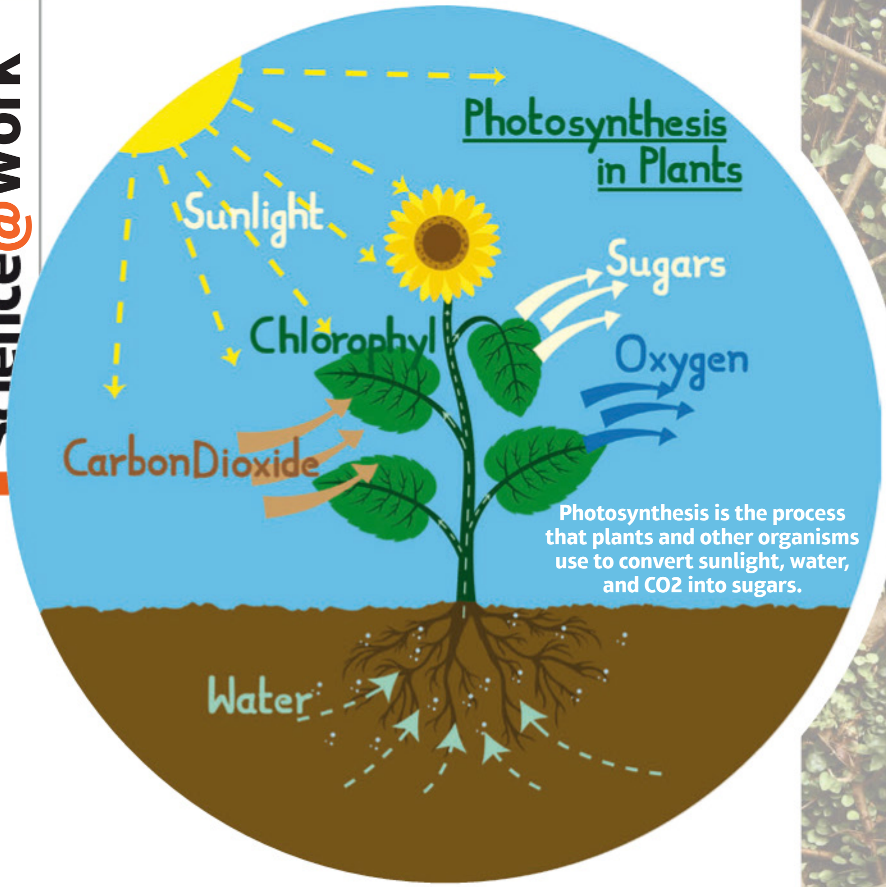
My discovery was that mycorrhizae actually connect many trees in a forest—even trees of different species and ages. What's even more remarkable is that trees share with one another through this vast underground fungal network. They share carbon energy, they even send messages, like warnings that leaf-eaters are attacking.

WHY DID YOU WANT TO STUDY TREE CONNECTIONS?

When I was a kid, I would sit in the forest and hear and see all these relationships around me, like a big family. Later, my first job was to plant baby tree seedlings in *clearcuts*. Clearcuts are the bare land left after foresters cut down all the trees. We killed trees that sprouted near our seedlings because we thought they competed for sunlight, shading out our seedlings. But the small seedlings died, so something in our understanding was missing. I suspected that if we'd left those other trees, they would have actually helped the seedlings survive. I longed to know how these trees related to one another.

WHAT EXPERIMENTS DID YOU DO TO DISCOVER TREES HELPED EACH OTHER?

In my first experiment, I used specially tagged carbon molecules. I could follow them as they were absorbed into the leaves by photosynthesis, turned into sugar, and moved inside the tree. When I followed where the tagged carbon went, I found something new and incredible: It moved from each tree underground into a mycorrhizae fungal network that connected the trees. Then it moved through the network into other trees, even *different species*. So, carbon that enters tree leaves through photosynthesis moves to other plants. That changed the world. And it proved what I'd guessed as a kid—the forest is a sharing community.

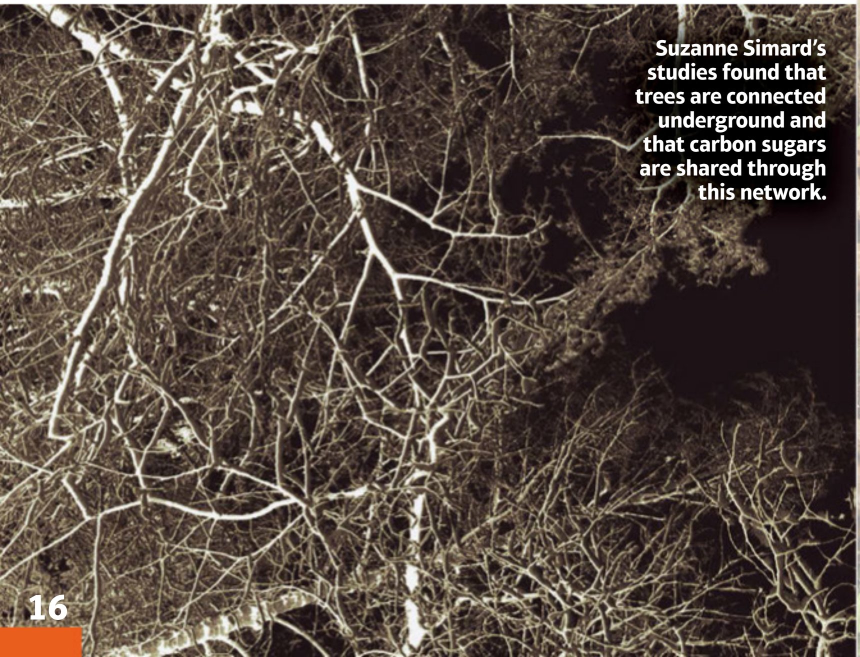


Photosynthesis is the process that plants and other organisms use to convert sunlight, water, and CO2 into sugars.

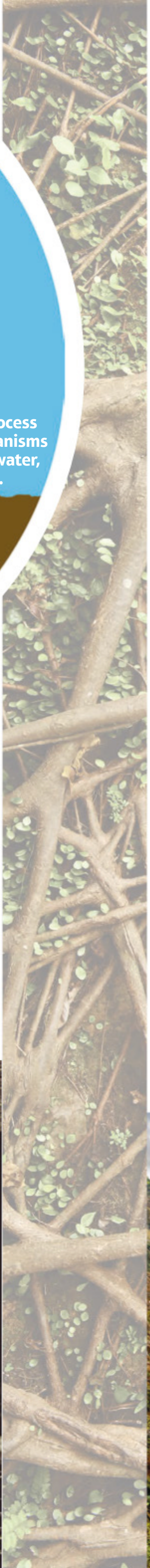
WHAT DOES THE UNDERGROUND NETWORK LOOK LIKE?

In a later study, my student and I went to a typical old-growth forest. It had trees of all ages: ancient trees hundreds of years old, middle-aged trees, and baby seedlings growing near their parent tree. We wanted to know how the mycorrhizal network connects trees. We peeled back the forest floor to expose the interwoven tapestry of fungus threads. There are hundreds of miles of fungal threads under every footstep. We used genetics to map where single threads went and how the trees were linked.

The map showed that everything is connected, but the biggest, oldest trees are at the center of the network, with the most connections. Carbon energy moves back and forth through the threads, but most comes from the biggest trees. It turns out there's a special relationship between the big trees and their relatives: They send more carbon energy to their own seedlings. We call them mother trees. Trees also send warnings.



Suzanne Simard's studies found that trees are connected underground and that carbon sugars are shared through this network.



WHEN THERE'S A SCIENTIFIC BREAKTHROUGH LIKE YOURS, SOME SCIENTISTS CAN BE CRITICAL. HOW DO YOU RESPOND TO CRITICISM?

When I first published my discoveries, many scientists thought they were untrue. At first, I took a long break. But the thing that I never lost sight of was how important the forest is for all of us. Our lives and forests are completely interdependent—if we lose the forest, we're going to lose ourselves. I love the science. I listened to the criticisms of my experiments and responded. But it doesn't ever distract me from my main goal, which is to protect the forest to protect ourselves.

DOES LOGGING THREATEN THIS FOREST COMMUNITY?

Yes. Most timber industries clearcut forests because it's easy and makes the most

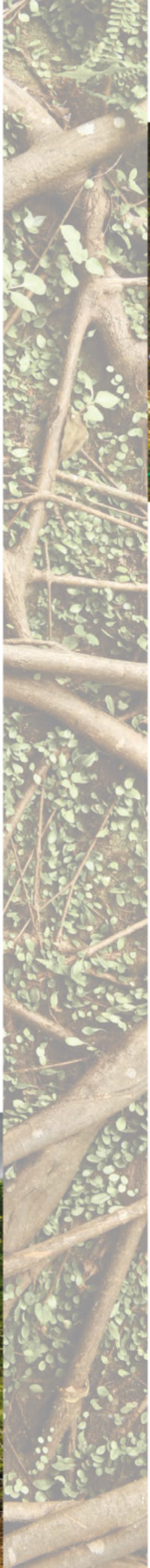
money. But clearcutting takes all the mother trees. When the mother trees go, the underground fungal community weakens. It shrinks from hundreds of species to just a handful, because there's no photosynthesis energy to feed them. After that, even when trees are replanted, the network takes a long time to regrow, maybe 50 or 100 years before trees are strongly connected again.

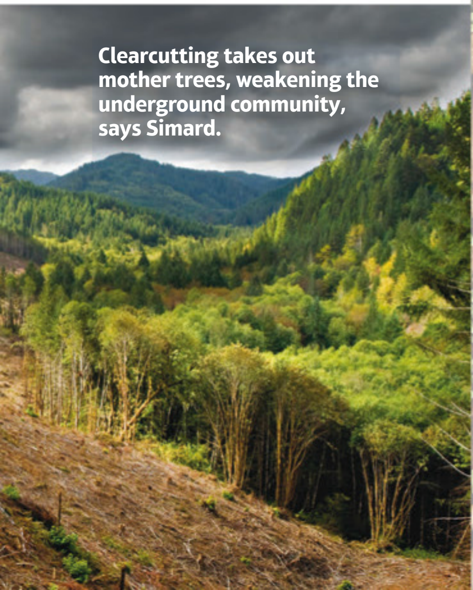
GIVEN YOUR DISCOVERIES, ARE LOGGING COMPANIES CHANGING?

Logging practices haven't really changed. I grew up in old-growth forests here in Canada. Since then, most of my home forests have been clearcut. We only have two to three percent of the ancient big-treed forests left. What has changed is the people of the world are saying, "Enough already, we can do better." The United Nations just voted to save 30 percent of Earth's forests by 2030—only seven years away—including saving all old growth forests. That's a massive change.

HOW CAN KIDS GET INVOLVED?

The easiest way is to sit with trees and listen, maybe write or draw. Let them be part of you. Bring family and friends. Next, get your hands in the dirt and plant a tree. Then, visit it over time and watch it grow. But the most important, and hardest, is to help parents and teachers understand the importance of not logging old forests. Encourage them to help you get involved in ways to stop old-growth logging, because once the ancient mother trees and their networks are gone, they're gone forever.





Clearcutting takes out mother trees, weakening the underground community, says Simard.

Drawing or writing outside is one way to grow closer to trees.

Planting a tree with friends and family can be a satisfying way to contribute, says Simard.

ARE YOU HOPEFUL THE FORESTS CAN HEAL?

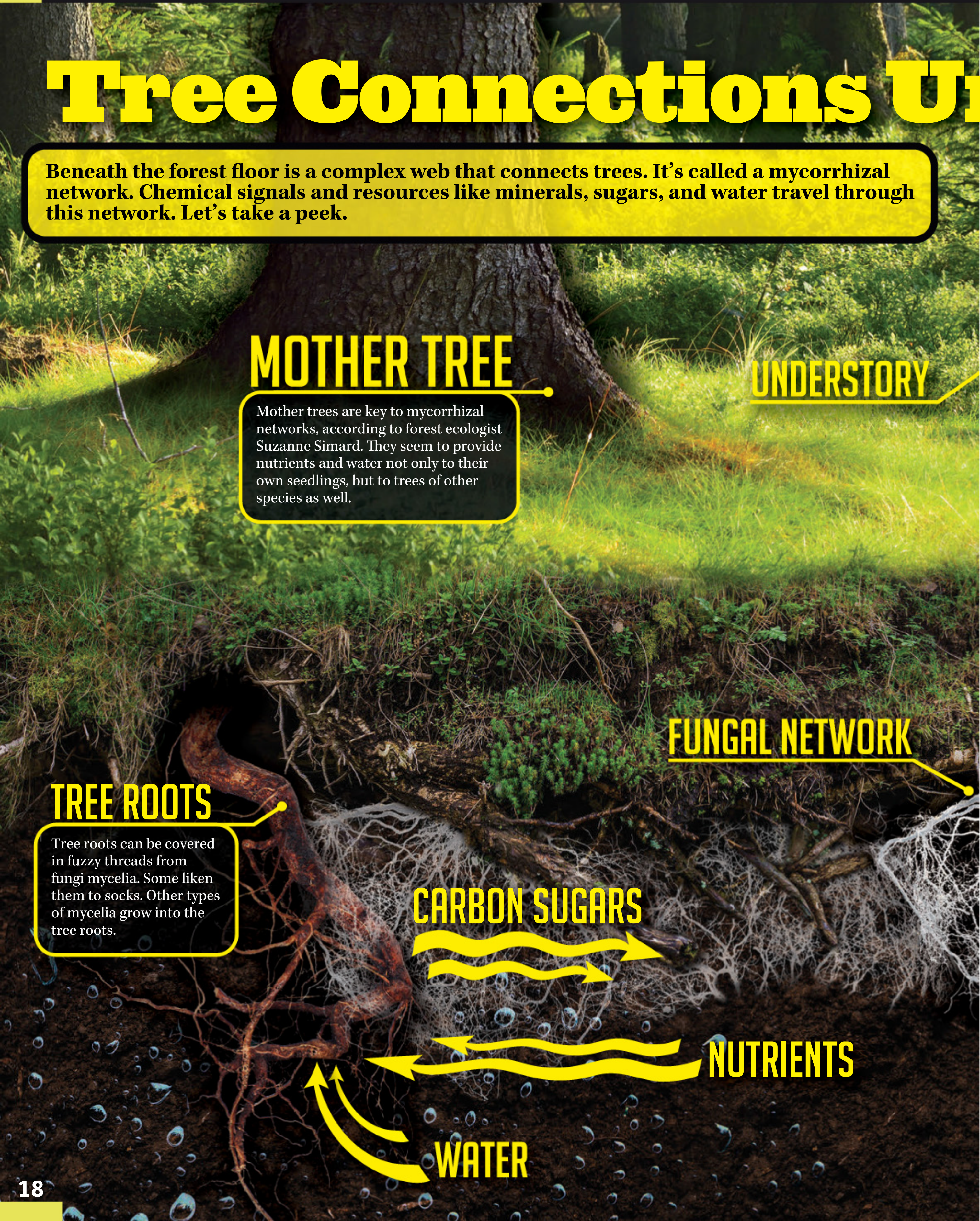
Yes, because of the connectedness of forests. Those many connections make the forest really resilient. If one thread breaks, there are hundreds of other threads to replace it. If some trees are cut down, there are others to provide carbon. The network can grow back together quickly after the forest is damaged. Especially if we keep the mother trees because they are at the center, with the most connections. A networked forest is a healing forest.

Jeanne Panek is part forest ecologist, part writer, and part wilderness explorer. If she had mycorrhizae buddies, she would feed them sour gummies in exchange for stories of life underground.

DESIGNED BY HARRISON HUGRON

Tree Connections U

Beneath the forest floor is a complex web that connects trees. It's called a mycorrhizal network. Chemical signals and resources like minerals, sugars, and water travel through this network. Let's take a peek.



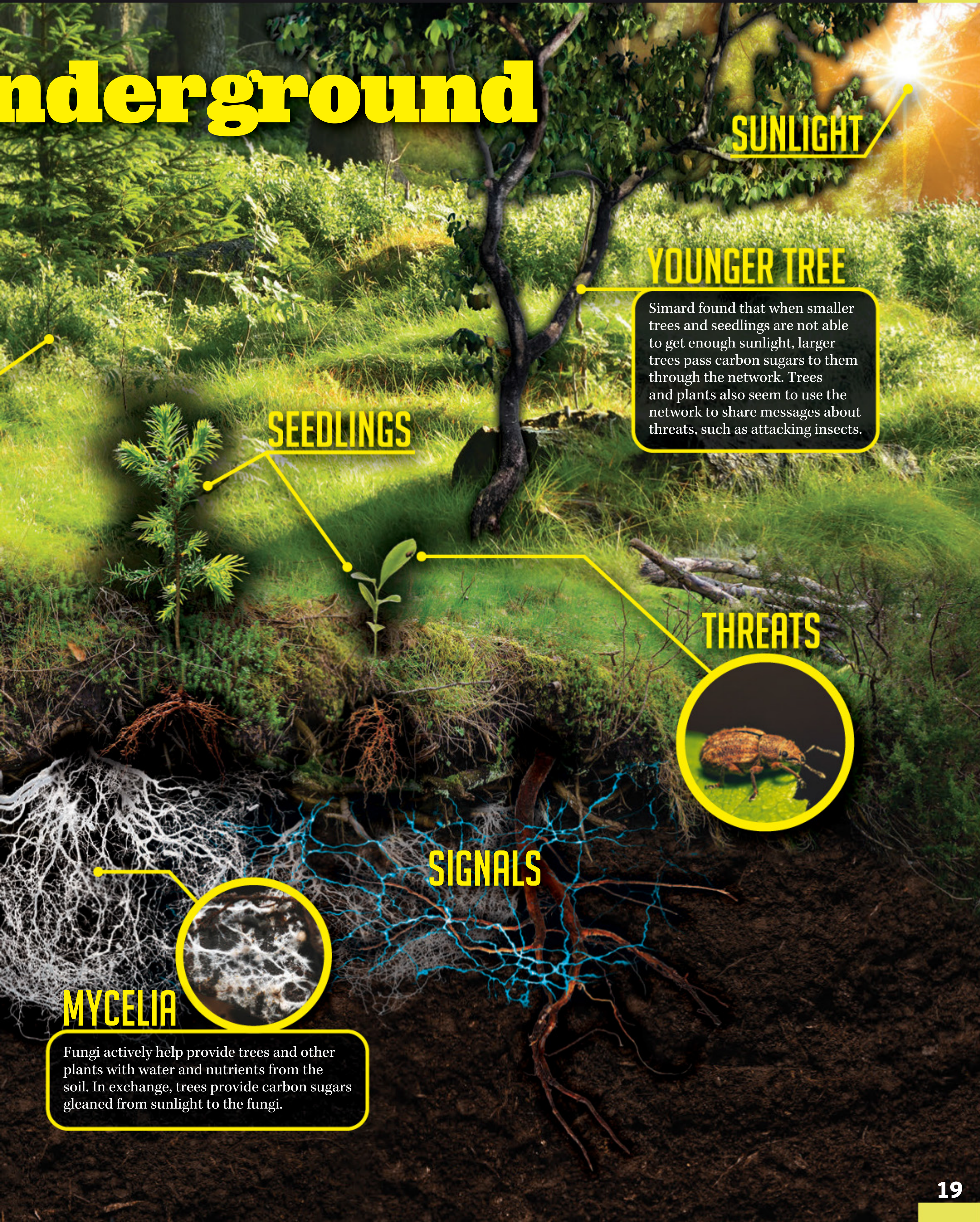
MOTHER TREE

Mother trees are key to mycorrhizal networks, according to forest ecologist Suzanne Simard. They seem to provide nutrients and water not only to their own seedlings, but to trees of other species as well.

TREE ROOTS

Tree roots can be covered in fuzzy threads from fungi mycelia. Some liken them to socks. Other types of mycelia grow into the tree roots.

nderground



YOUNGER TREE

Simard found that when smaller trees and seedlings are not able to get enough sunlight, larger trees pass carbon sugars to them through the network. Trees and plants also seem to use the network to share messages about threats, such as attacking insects.

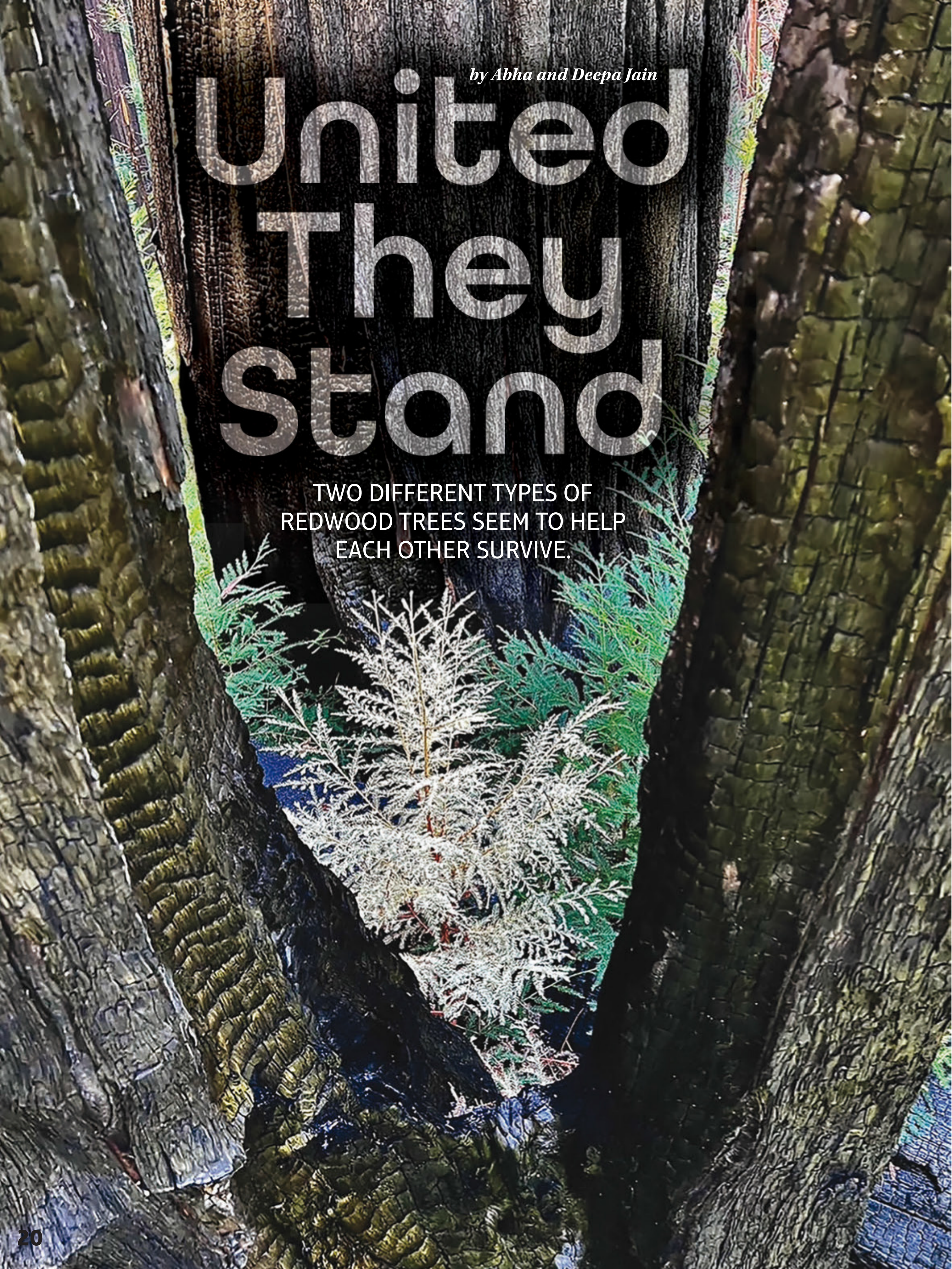
MYCELIA

Fungi actively help provide trees and other plants with water and nutrients from the soil. In exchange, trees provide carbon sugars gleaned from sunlight to the fungi.

by Abha and Deepa Jain

United They Stand

TWO DIFFERENT TYPES OF REDWOOD TREES SEEM TO HELP EACH OTHER SURVIVE.



One wet winter's day, high school student Zane Moore strolled through the Henry Cowell Redwoods State Park in Northern California. He watched raindrops splatter the green leaves and the brown trunks of coastal redwoods. Then his jaw dropped. In a ring of dark redwoods shone a solitaire, a tiny tree so "vibrant white," Moore says, that it shocked him. A white tree that wasn't covered in snow? How was this possible? Now a graduate student in botany at the University of California, Davis, Moore has been working to understand the answer to this question.

Pearls in the Forest

Forests of thousands of coastal redwoods cover the mountains of Northern California and Oregon. They almost look like deep green seas. But concealed beneath this canopy, along the forest margins, are about 400 smaller, paler trees. These are "albino" redwoods. "Most begin as sprouts or twigs arising directly from a parent tree," says Jarmila Pittermann. She's a plant biologist at the University of California, Santa Cruz.

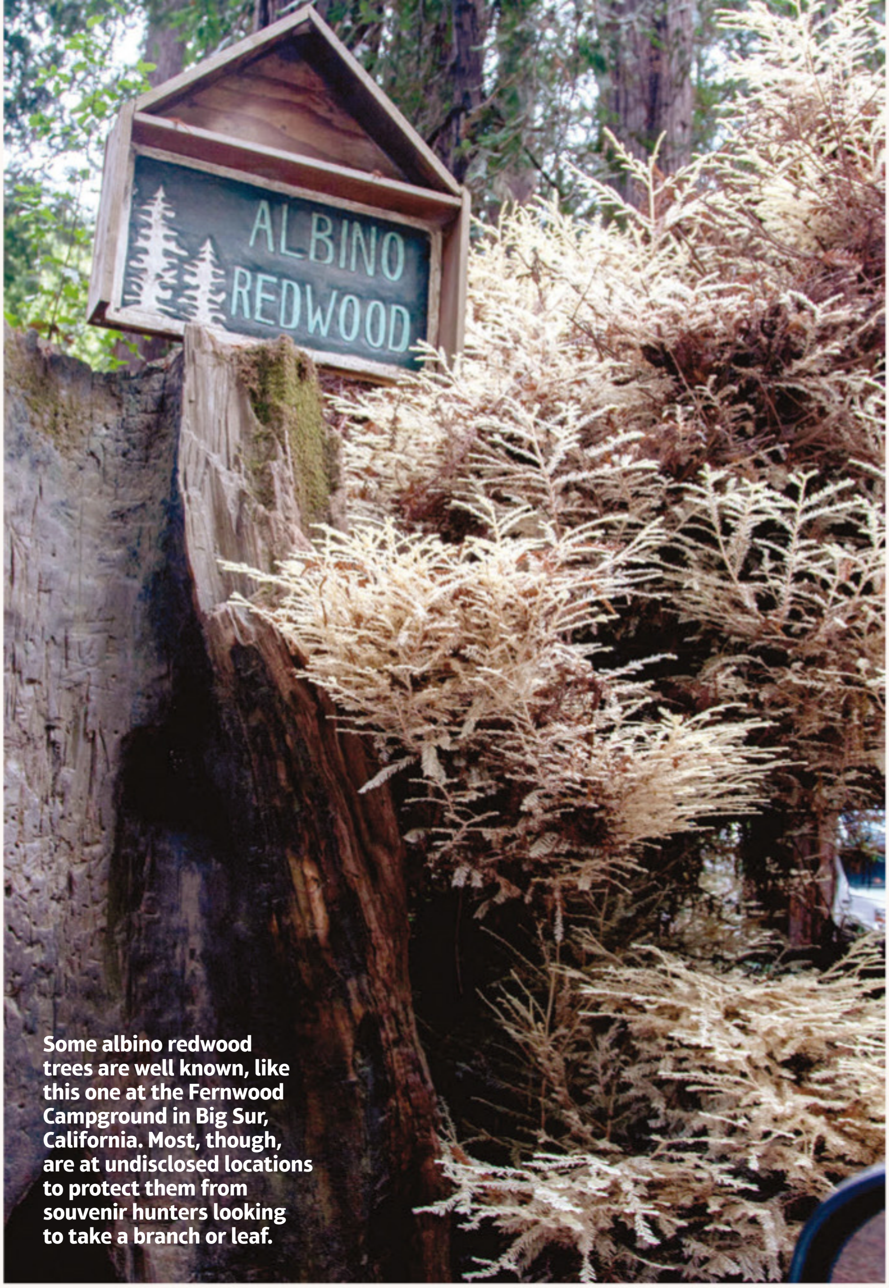
Albino redwoods look the way they do because they have a problem making *chlorophyll*. That's the pigment that gives leaves—called needles in redwoods and other conifers—their typical green color. Some redwoods cannot make any chlorophyll. This gives their needles a snow-white color. Other albino redwoods produce just a tiny amount of chlorophyll. Their needles' hues range from creamy yellow to light green.

Color isn't the only difference, though, between albino redwoods and their green buddies. The pale trees are pretty puny, growing to a maximum of 60 feet (18 meters). That may seem tall, but it's four times shorter than an average green-leaved redwood. With a typical height of about 240 feet (73 meters), green redwoods are the tallest trees in the world.

Plus, albinos' needles are softer and thinner than those of green redwoods. And openings in the needles called *pores* don't close properly. Leaves of all trees have these openings. They help in the exchange of gases like water vapor between the inside of the leaves and the outside atmosphere. Because of how their pores work, albinos lose lots of water.

Yet, there's a far more fundamental challenge albino redwoods face: food. Plants generally make their own grub

The brilliant white of some albino redwood trees sharply contrasts with the rich green of their chlorophyll-laden counterparts.



Some albino redwood trees are well known, like this one at the Fernwood Campground in Big Sur, California. Most, though, are at undisclosed locations to protect them from souvenir hunters looking to take a branch or leaf.

through a process called *photosynthesis*. They convert carbon dioxide and water into simple sugars, also called "carbon" for short. This process requires both energy from sunlight and the plants' own chlorophyll. With little to no chlorophyll, albino redwoods find it nearly impossible to harness the Sun's energy and produce carbon. How can these pale trees survive, let alone thrive?

Binding All Together

It turns out that the survival of these shoots depends on the species' roots. You might think a tall redwood would have very deep roots. That isn't the case. Redwoods have shallow root systems for their size, reaching only about 12 feet (four meters) below the soil. But they make up for what they lack in depth by stretching very far horizontally, up to 80 feet (24 meters). That's roughly the length of a competitive swimming pool.

The roots of redwoods intertwine with the roots of trees around them, like people clasping hands together. And just as breaking through linked hands is difficult, ripping apart the redwoods' interlinked roots would be tough. This gives redwoods the stability to stand tall in the face of challenges, such as high winds.

But the albino redwoods have an even more special connection with the trees around them: They share their roots with their parents. This means, says Pittermann, that "their vascular system is directly linked to that of their parent." The vascular system is what carries food, water, and more throughout the body of an animal or plant. Through this vascular system, "albino leaves acquire resources from the parent without providing anything in return," says Pittermann.

The albino trees may also get resources from fungi that form networks with tree roots. Fungi provide nutrients to trees in exchange for carbon, and trees seem to trade resources with each other. Scientists, though, haven't yet figured out how this might work in the networks linked to green and albino redwood trees.

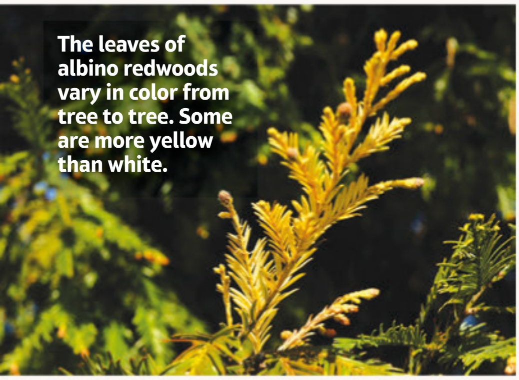
A redwood tree has a complex root network, often connecting it with dozens of nearby trees.

Green *and* white!

CHARISMATIC CHIMERAS

Chimeric redwoods look like a mishmash of albino and green redwoods. They're named after a Greek mythological monster, the Chimera, a fusion of a lion, a goat, and a serpent. Some chimeric redwoods have entirely separate white and green branches. On others, green and white needles grow from the same stalk.

Tree specialists have developed commercial varieties of chimeric redwoods that you could buy and grow. Their most significant use, though, might be in areas contaminated with heavy metals. By accumulating these chemicals, chimeric redwoods could clean the soil, making it safe for other plants.



The leaves of albino redwoods vary in color from tree to tree. Some are more yellow than white.

So, do the albinos rob green redwoods of all their food? Nope. Green redwoods are efficient chefs. A large one produces enough food to add roughly 1,500 pounds (680 kilograms) of new wood in a year. Since albinos never get huge, they require a much smaller quantity of food. In other species of conifer, albino plants lack a parental support system and cannot thrive beyond the sapling stage.

In *chimeric redwoods*, white needles grow alongside green ones. In this case, the white needles get their food from green companions that may be mere inches away.

Parasites or Protectors?

So, green redwood trees and needles definitely feed their white companions. But why?

Green redwoods, Moore notes, "either promote branches or get rid of them depending typically on their 'usefulness.' If a branch can't photosynthesize for itself, the tree sheds it." Then why are these pale freeloaders kept alive?

Moore resolved to find out. His first step: figuring out how exactly albino redwoods differ from green ones, beyond the obvious lack of chlorophyll.

He focused on the anatomy and the chemical composition of needles he collected with the help of park guardians and redwood enthusiasts. Perhaps, he thought, the albinos' leaves have an unusual internal structure. Or maybe they contain abnormal amounts of some chemical element that the plants need.

One of his experiments measured the levels of elements called *heavy metals*. Such metals include nickel and copper. They form part of proteins that help plants breathe and grow (and you, too!). That's why, in small amounts, heavy metals can be helpful.

Beyond a certain amount, though, heavy metals are poisons. They stop or slow down life-giving processes, such as photosynthesis. But Moore's research showed that white redwood leaves were remarkable. They contain twice the heavy metal levels as green redwoods. This means the toxicity limit for white redwoods is much higher than that of their green counterparts.

Two reasons may explain why albinos hoard high levels of heavy metals. Whenever water escapes from needles as vapor, some suspended heavy metals get left behind and accumulate. Since albinos' pores lose water rapidly, they have to take up more water (and more heavy metals) to compensate. Plus, since no photosynthesis takes place in albino redwoods, large concentrations of heavy metals cannot slow food production here. White trees and needles may act as sinks for these dangerous chemicals.

So, maybe albino redwoods aren't mere parasites after all. Do they exist to protect green redwoods by absorbing their heavy metals? Moore isn't sure. "We cannot 'prove' this without greenhouse experiments," he says. But it *is* undoubtedly true that albinos can survive toxins that would poison their green counterparts.

Rain still occasionally pelts the leafy dwellers of the Henry Cowell Redwoods State Park. Sometimes the area swells with fearsome floods. But redwoods, notes Pittermann, are resilient. And the different types of redwood trees demonstrate this by supporting one another in their own unique ways. They ensure that standing together, all redwoods can survive.

Abha and Deepa Jain are a twin writing team. Redwoods are among their favorite trees, though they think weeping willows are pretty, too (despite their sad name).

Skyw

by Jeanne Miller

Coast redwood trees grow in a narrow band from southern Oregon to central California, where rain and fog are typically abundant.

Aloft in Redwood Space

alking
FOR SCIENCE

When Stephen Sillett climbed his first giant redwood tree, back in 1987, he didn't know that a new world awaited him up there.

At that time the tops of the ancient trees in old-growth redwood forests were unexplored. Scientists assumed they were biological deserts, containing only tree branches. But when Sillett reached the crown of the 300-foot (91-meter) tree, he found a forest above a forest. At its top was a sunny glade alive with mosses, lichens, and even small trees. Growing from a rotting stump in the middle of the crown were huckleberry bushes, laden with berries. It was a thriving ecosystem in the air.

Sillett started climbing trees when he was a student at Reed College, in Portland, Oregon, in the 1980s. Those experiences led him to become a *botanist*, a scientist who studies plants. Today, he teaches botany and forestry at Humboldt State University in Northern California and spends much of his time at the top of tall trees. Coast redwood trees (*Sequoia sempervirens*) are his specialty.

An Aerial World

The coast redwood is one of three surviving species of redwoods. (The others are the giant sequoia in the Sierra Nevada Mountains in California and the dawn redwoods in China.) It grows only in a narrow band along the Pacific coast between central California and southern Oregon, a 450-mile (724-kilometer) belt where rain and fog provide enough moisture to sustain the giants. They are the tallest trees on Earth and have been around for 10 million years. Some coast redwoods living today may be as old as 2,000 years. The oldest and largest ones survive in old-growth forests, most of which are protected in parks or reserves. These are the trees that Sillett and his colleagues study.

Redwoods are remarkable for their ability to stay alive, whatever happens. If some accident exposes the living tissue under the bark, a sprout grows from the wound. So, if a limb breaks off, another limb arises in its place. If the top of the trunk dies and

Stephen Sillett is a forest ecologist who has spent a lot of time climbing coast redwoods, the tallest trees in the world.

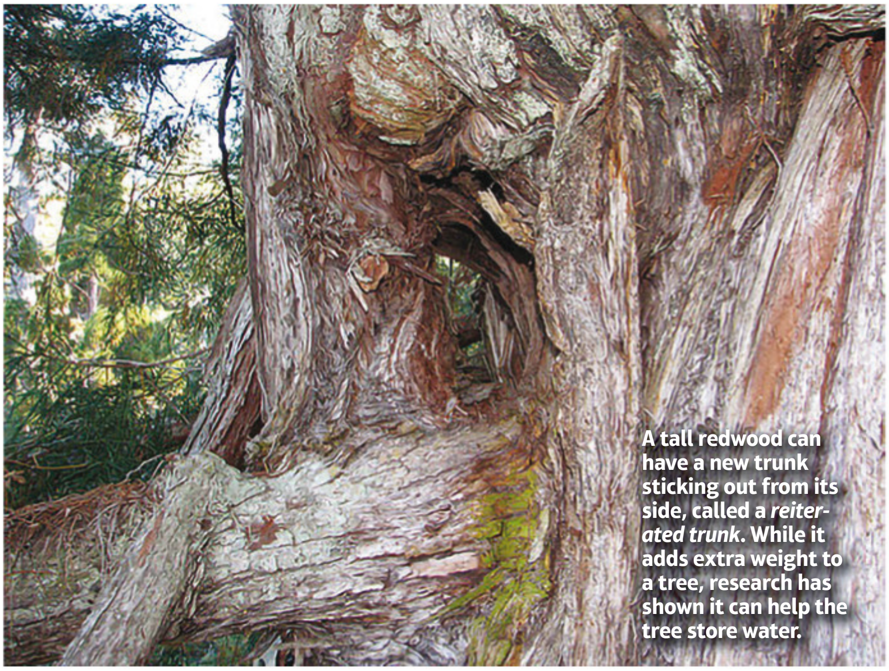
falls off, another trunk shoots up from that spot. And if that trunk breaks off, another trunk will grow. The crown of an old redwood often has many trunks, each with its own set of branches.

This complex structure, trunk upon trunk, limb upon limb, creates pockets where dry redwood needles collect. Fungi grow on the dead needles and decompose them into soil. Into this soil drop airborne seeds and spores. Plants sprout, mature, reproduce, and die, enriching the soil and making it ever deeper. In the redwood canopy, nestled in nooks and crannies and on flat limbs, Sillett and his tree-climbing team have discovered rhododendrons in bloom as well as miniature trees of many species: hemlocks, Douglas firs, and tan-oaks among them. They've even found an eight-foot (two- to three-meter) Sitka spruce rooted on a limb of a redwood. Dense aerial gardens of ferns host a variety of animal life, including slugs, snails, and salamanders. These fern mats store moisture that supports much of the life in the uppermost layer of a forest, the canopy.

Mapping Redwoods

Sillett and his colleagues want to understand how these trees operate and what their limits are. They've installed sensors in several trees to

Coast redwood trees can reach as high as a 30-story skyscraper, putting their tops out of sight. Their trunks can reach 27 feet (eight meters) across.



A tall redwood can have a new trunk sticking out from its side, called a *reiterated trunk*. While it adds extra weight to a tree, research has shown it can help the tree store water.

The soft bark on branches hundreds of feet off the ground makes a perfect foggy home for moss and fungi.

collect data on light, temperature, humidity, wind, and sap flow. In addition, he and his students measure the diameter and position of all the woody parts of the redwoods. Sillett uses these numbers to construct 3D (three-dimensional) diagrams of each tree. He hopes to be able to explain someday how and why the trees are different from one another.

The researchers want to know how water moves through their trunks and branches. It takes water a few weeks to get from the redwood's roots to its top, traveling up through microscopic channels in the trunk. Water molecules have a tendency to cling to one another, so as a water molecule rises it pulls the next molecule with it. When water evaporates from the leaves at the top of the tree, more water rises to replace it. But it's a fight against gravity, and scientists think there's a limit to how high the water can be pulled. And that puts a limit on how high a tree can get. Coast redwoods have an advantage over many trees, in that they are bathed in fog on summer mornings. In recent years, though, drought has reduced the amount of available fog. Scientists working with Sillett have discovered that 25 to 50

Researchers are extensively trained before ascending redwoods. And, not surprisingly, they need to be super comfortable with heights.

A STRANGE ZOO IN THE SKY

In the redwood forest canopy, Stephen Sillett and his team found more than hanging gardens. They also found some startling animal life. Clambering around among the ferns were wandering salamanders. Having no lungs, the wandering salamander needs moist skin to breathe. Healthy populations of up to 29 salamanders in each of several trees attest to the canopy's capacity for holding water. These contented creatures spend their entire lives in the treetops, never seeing the forest floor below.

Another surprise was the presence of copepods, little crustaceans that usually live in the sea or in fresh water. How did they get there? Nobody knows. Perhaps hitching a ride in a bird's beak.

Communities of slugs and snails, crickets and millipedes, earthworms and newts thrive in this habitat in the air. Endangered species of birds also nest there. The spotted owl and the marbled murrelet, a sea bird, are among the animals that make their homes in the highest trees. In fact, the National Park Service bans climbing in the redwoods from September through January so these birds won't be disturbed during their nesting season.

Wandering salamander

Banana slug

Spotted owl

People have long been in awe of redwood trees, but many were surprised by the discovery of thriving ecosystems in their crowns.

percent of a coast redwood's water comes from summer fog, much of it taken up by the canopy soil.

Sillett and a fellow researcher hang from ropes for safety and to avoid damaging the delicate environment of the trunk.

Taming the Tallest Trees

The very tallest redwoods all grow in a few state parks and a national park along the northernmost coast of California. There are four trees over 370 feet (113 meters) in height and Sillett has climbed them all. *Laser range finders*, devices that use laser beams to measure distance to an object, can determine the height of a tree within a few feet. The only really accurate measurement, however, comes from climbing to the top and dropping a measuring tape to the ground. The tallest tree in the world was discovered in 2006 in Redwood National Park in Humboldt County, California. Sillett measured it at 379 feet (116 m) high. That's the height of a 37-story building.

Canopy researchers face many difficulties, and getting to the top of a tree is just one of them. Hiking through an old-growth redwood forest is the first challenge. These are temperate rainforests, which, like their tropical cousins, typically have abundant rainfall. The forest floor is thick with lush undergrowth. Fallen redwood trunks, some as much as 12 feet (3.7 meters) in diameter, often lie in the way. It can take hours of bushwhacking to go just a mile.

Sillett has made an art of climbing the ancient redwoods, but he can't completely eliminate the danger. It requires extreme discipline and focus to stay safe that high off the ground. A moment of inattention can result in a fatal fall. Redwoods drop dead branches without notice. Climbers call these "widow makers." Even if you're paying attention, you could become the victim of dead wood.

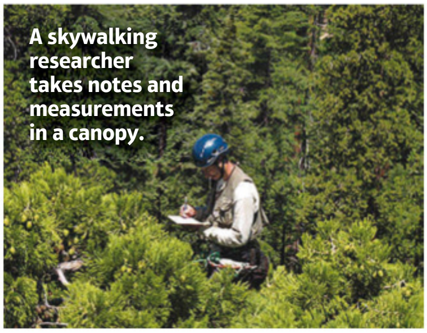
Just as important to Sillett and his team as their own safety is the safety of the fragile ecosystems in the canopy and of the tree itself. Sillett calls this area "redwood space." The climbers hang in harnesses from ropes when

HOW TO CLIMB A GIANT

Most canopy researchers have adopted the tree-climbing techniques Sillett uses:

- Using a powerful hunting bow, he shoots a rubber-tipped arrow toward a sturdy limb. Sometimes the first sturdy limb is 200 feet (61 meters) up.
- The arrow drags a fishing line with it over the limb.
- He ties a cord to the fishing line and then a climbing rope to the cord.
- As he reels in the fishing line, the rope is hauled up into the tree and over the limb. Now two ends of the rope dangle from the limb. He secures one end to a small tree.
- He puts on a helmet and a harness and clips mechanical ascenders to the other end of the rope; these devices slide freely in one direction but grip the rope when pulled in the opposite direction.
- He attaches his harness to one of the ascenders and with the other he pulls himself up the rope, one arm-length at a time, to the limb.
- From that limb he tosses a weighted rope over a higher branch and climbs to that branch, then repeats this until he's where he wants to be in the crown.
- There he uses shorter lengths of rope to anchor himself to other parts of the crown so that he can move around freely.

And you thought your tree-climbing skills were advanced!



A skywalking researcher takes notes and measurements in a canopy.

they're in the trees to avoid putting their full weight on the branches they're exploring. These rope systems allow them to move all around the crown, even to the tips of the farthest branches. Traveling over these webs of ropes is known as "skywalking."

The Future of Old-Growth Redwoods

It's not easy to kill a mature redwood. The trees are immune to most diseases. Sometimes a series of fires will hollow out a cavern in a redwood trunk, but the tree keeps growing. Early settlers used to house their poultry in fire caverns at the base of the trees. (These cavities are still known as "goose pens.") Builders value redwood lumber because the *heartwood*—the cinnamon-colored wood at the center of the log—is resistant to rot and insects. And that's a big reason why only four percent of the country's old-growth redwood forests remain today. Commercial logging of redwoods came in with the California Gold Rush in the 1850s. Redwood trees built old San Francisco. And they built it again after the 1906 earthquake.

In the early 1900s, some Americans who were concerned about the disappearing stands of ancient redwood founded the Save the Redwoods League. We have the League to thank for establishing the publicly owned preserves within the Northern California state parks that exist today. But logging of old-growth redwoods continues on privately owned land.

Sillett wants to see a better process for selecting which redwoods should be logged in existing forests. He has found that a redwood's yearly rate of growth keeps increasing until it's 1,500 years old. The older the wood, the better the wood, with more decay-resistant heartwood.

The Save the Redwoods League launched an initiative to explore how redwoods might react to climate change. Sillett has been one of the scientists leading this effort. One thing that we already know is that redwood forests are champions at capturing carbon dioxide from the atmosphere and storing it. That's an important component of slowing climate change. Sillett has recommended planting more redwoods in areas where they might thrive, such as the Oregon coast, and letting them become the old forests of the future.

Redwoods were here long before humans and they should be here long after we're gone. We have to make sure we don't get in the way of that.

Jeanne Miller once spent 10 days camping and hiking in Redwood National Park. She feels fortunate to walk by redwoods every day in Berkeley, California, where she lives and writes.

BY NICK D'ALTO

THE TREE DA VINCI CODE

Does a 500-year-old sketch explain how all trees grow?

The Renaissance artist Leonardo da Vinci (1452-1519) painted beautiful trees in the backgrounds of some of his masterpiece paintings. He was also a visionary scientist. And on a single page of his extraordinary notebooks, this all-around genius hit on a remarkable theory about trees. He wrote and illustrated a simple mathematical formula that might explain how all trees grow.

Five hundred years later, modern-day experts have finally put da Vinci's formula to the test. They have subjected it to our 21st-century science. So, does the da Vinci code for trees still stand up?

Look at a Tree

Beginning from its trunk, a tree's branches grow smaller as the tree rises. The tree branches into more, smaller stems the higher it goes. That's not a secret. But da Vinci, who enjoyed tackling scientific problems, wanted to know more. He sought to understand precisely how much thinner its branches became.

Here was his amazing insight:

"At any height on the tree, the area of all the branches always adds up to the area of the trunk."

Examining Da Big Idea

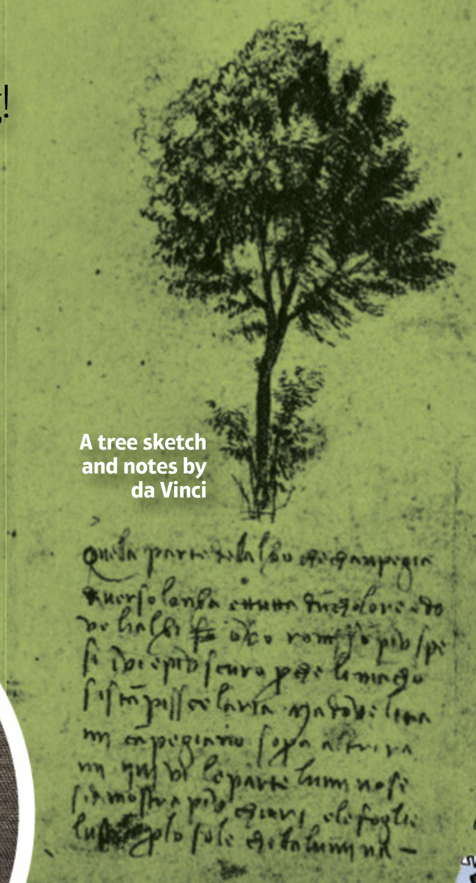
Imagine that a circular sliced section of a tree's trunk has an area of 100 square inches (645 square centimeters). According to da Vinci, if that trunk divides into two equally-sized branches, they should measure 50 square inches each. Then these might each divide into smaller branches that don't necessarily have to be equally sized. For example, two might measure 20 and 30 square inches, or three 20, 20, and 10. Da Vinci figured this would hold true up to the finest branches at the tree's top.

Notice something amazing here. Using da Vinci's formula, if you could "squeeze" all the branches of the tree back together (like a big umbrella), you'd get a uniformly thick rod. According to this idea, the amount of wood on a tree should be the same at any height!

Now Remember Your Math

Since a tree's branches are nearly round, we can model the area of their cross sections using the areas of circles. (The formula to find the area of a circle involves it radius, which is the distance from the circle's center to a point on its circumference, its edge.) Here's an example. Say a tree's trunk measures 10 inches across; that's its diameter. Its radius is half its diameter, so this one would be five inches. Meanwhile, according to the formula,

> “Leonardo’s rule is an amazing thing! Until recently, people really hadn’t tested it.”
>
> *- Kate McCulloh, Plant Physiologist, Oregon State University*



A tree sketch and notes by da Vinci

Leonardo da Vinci (1452 - 1519)

its area is about 80 square inches. According to da Vinci, each branch should measure half that, or 40 square inches each.

But here’s the surprise. A circle with half the area doesn’t span half as much across. Using the circle formula, we find that the branches from a 10-inch trunk measure about seven inches wide, not five inches! That’s because the total wood stays constant as the tree rises.

His branching formula helped da Vinci paint and draw trees that looked lifelike. Today, some painters, movie visual effects artists, and computer programmers use it to create realistic-looking trees in their works. Naturalists who measure the branches of real trees confirm that they follow “Leonardo’s rule,” or an updated version of this tree da Vinci code.

About Science

Beyond art, da Vinci wanted to understand how trees grow. Why might trees keep their wood constant as they branch? One answer, according to da Vinci, is water. Trees lift water from their roots to their leaves in their sap. This sap must distribute among all branches, so with less sap more distant branches might grow smaller. Today’s scientists have another answer: strength. Trees are “built” from wood, so they shouldn’t carry more wood on the top than on the bottom. Following da Vinci’s formula could help a tree resist wind.

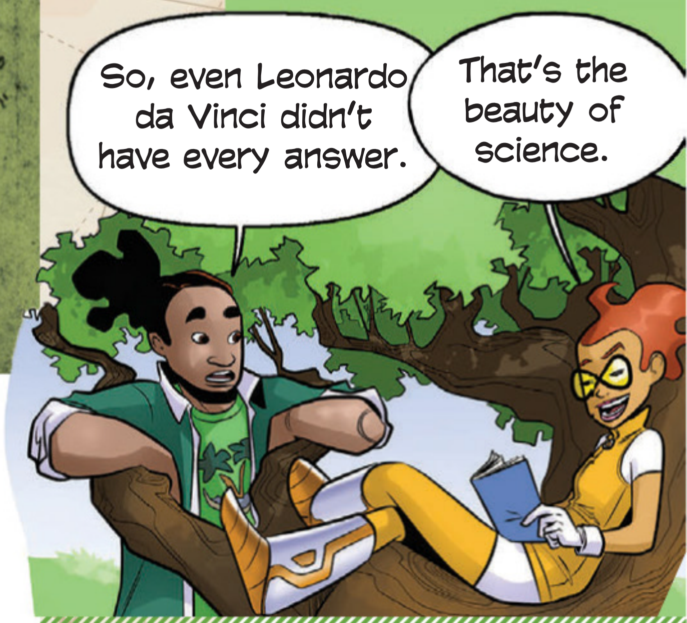
In one test, researchers set up a virtual wind tunnel. They found that da Vinci-shaped trees survive the strongest storms.

Da Vinci’s insight was based on simple math, plus a keen artist’s eye. No doubt, the genius inventor and scientist would have loved that today’s researchers have confirmed these ideas using modern science.

Nick D’Alto is a writer and aerospace engineer. He has invented his own rule for trees; they all seem to drop their leaves in his yard.

IMPROVING ON GENIUS

In his notebooks, da Vinci studied other ways that trees grow. He looked at how their branches tend to grow shorter, higher on the tree. Recently, Russian scientists incorporated this idea into da Vinci’s original formula. By adding extra math to also model the lengths of the branches, researchers found a revised formula that makes an even better fit with real trees. They tested it with maple, apple, oak, chestnut, and birch trees. This formula adds a new dimension to this already ingenious idea!



So, even Leonardo da Vinci didn’t have every answer.
That’s the beauty of science.

A fractal is a geometric pattern that repeats again and again.

by Nick D'Alto

TREE-MENDOUS!

Draw a forest with fractals.

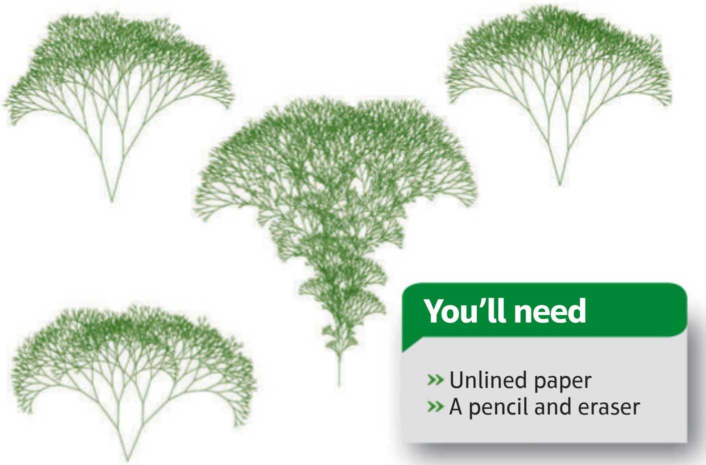
YOU MAY HAVE HEARD THAT NO TWO SNOWFLAKES ARE ALIKE, AND THAT TINY ACORNS GROW INTO MIGHTY OAKS. But how does that work, exactly? Consider that many of nature's most complex forms are based on simple geometric shapes.

The secret lies in repeating these shapes again and again. Often the repetition occurs at different scales: big to small, or small to big. The resulting shapes are called *fractals*.

They describe many of nature's most amazing shapes. Some flowers, including Queen Anne's lace, form a fractal shape. Pinecones are fractals. (Their scales vary slightly in size and in a spiral around the cone.) So are a bird's feathers and the jagged legs of lightning bolts. The shapes of continents are fractals, too!

Scientists and mathematicians study fractals to help understand the natural world, while engineers sometimes use them to devise new structures. Fractal shapes, for instance, form France's Eiffel Tower. Artists and craftspeople often use fractals to produce beautiful objects.

You can think of fractals as mathematical "instructions" for assembling lots of the things in our world. Why not try some of these instructions yourself?



You'll need

- Unlined paper
- A pencil and eraser

A Fractal: 'Wood' You Believe It?

1. Start by drawing a vertical line.
2. From the top of that line, draw a large letter *V*.
3. Now from each point of your *V*, draw another *V*, about half the size.
4. Repeat the previous step. From each *V*, draw more *V*s, each one smaller and smaller.

In real trees, branches tend to get narrower as the tree rises. In your fractal trees, try using thinner lines as you draw.

The resulting shape resembles how the limbs of trees and other plants branch and divide as they grow. Scientists call an arrangement of leaves or branches *phyllotaxis*. Plants grow by producing hormones that cause new branches to form and then extend to optimal length.

Different species of trees use slightly different "formulas." Trees with upswept shapes, such as poplar, tend to branch in narrow *V*s. Spreading trees, like a maple or chestnut, make much wider *V*s. Can you draw different species of fractal trees?

Let's Add All This Up

Try drawing many trees. Wow, a forest! That's *tree-mendous*!

Of course, these are just some examples. Once you start looking, you'll find fractals everywhere.

Nick D'Alto is an engineer who appreciates fractals in trees. He also likes fractal snowflakes because they're organized, easy to measure, and don't melt right away.

BY ROBERT J. COONTZ

Q:

What would happen if everybody in the world jumped into the air at the same time? With all that mass suddenly off the world, would it go spinning out of orbit, or what?

—Anonymous reader

A: Not even close. Benjamin Fong Chao is a geophysicist in Taiwan who has worked with NASA and studied how movements on Earth's surface affect its rotation. He says, "The total mass of the entire population is minuscule compared to Earth's." So, even if everybody squeezed together in the same place and jumped three feet (one meter) into the air, they would budge our planet by no more than 1/10,000 the size of an atom.

The effect on Earth's spin would also be tiny. It would be, he says, "much smaller than, say, the influences from tides or solar wind or building a large dam." It would be even smaller if people stayed home to jump, because jumpers in different places would cancel one another out. Chao, though, calculates that such a worldwide jump would cause a minor earthquake of about a magnitude of 2.3—too small to do any real damage.

—Robert

Q:

Will space and time ever cease to exist?

—Sam L., California

A: Not exactly, but physicists think space and time will eventually get incredibly weird. Andreas Karch is a theoretical physicist at the University of Texas at Austin. He says, "Scientists can't see into the future, but we can see into the past." Because light takes time to travel across space, Karch says, studying light from distant stars shows what the universe looked like billions of years ago. "What we see is that our cosmos, very much like the surface of a balloon you pump up, has been expanding," he says, "and this expansion has been getting faster and faster over time."

Where is this cosmic growth heading in the far future? Physicists' calculations paint a grim picture. "The expansion of the universe will eventually get so fast that every single atom—or even every part of an atom—will sit all alone for eternity, in its own empty universe," Karch says. Particles will be so far apart that their light won't reach one another. In that dark, lonely future, space and time won't disappear, but they will mean something very different from what they mean today.

—Robert

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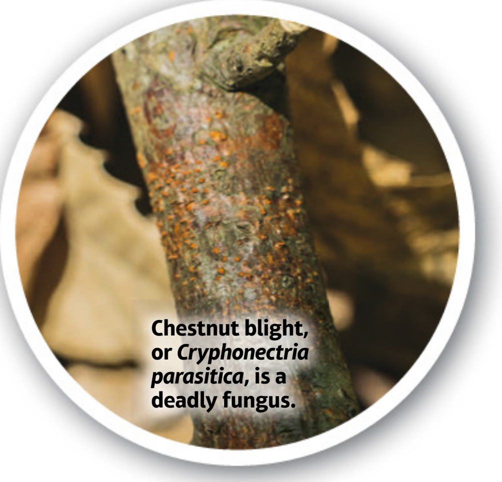
Bringing GIA

SCIENTIFIC EFFORTS TO RESTORE

Chief forester Hermann Merkel was worried. In the summer of 1904, he noticed areas of cracked, dry bark on the American chestnut trees in New York Zoological Park (known today as the Bronx Zoo). Tiny orange-red bumps dotted the bark like an angry rash. The injured bark was forming a *canker*—an area of dead tissue. The canker would eventually encircle the trunk and strangle the tree. Merkel suspected it was a fungus, but not one he'd ever seen before.



Chestnut blight, or *Cryphonectria parasitica*, is a deadly fungus.

Merkel was right to worry. *Cryphonectria parasitica*, also known as the chestnut blight, ended up killing an estimated four billion American chestnut trees. It was a devastating loss, especially in the Appalachian Mountains. There, people depended on the chestnut for food, livestock feed, and timber. In these Eastern forests, American chestnuts were giants, growing as tall as 100 feet (30 meters), with trunks 13 feet wide (four meters). Some were at least 600 years old.

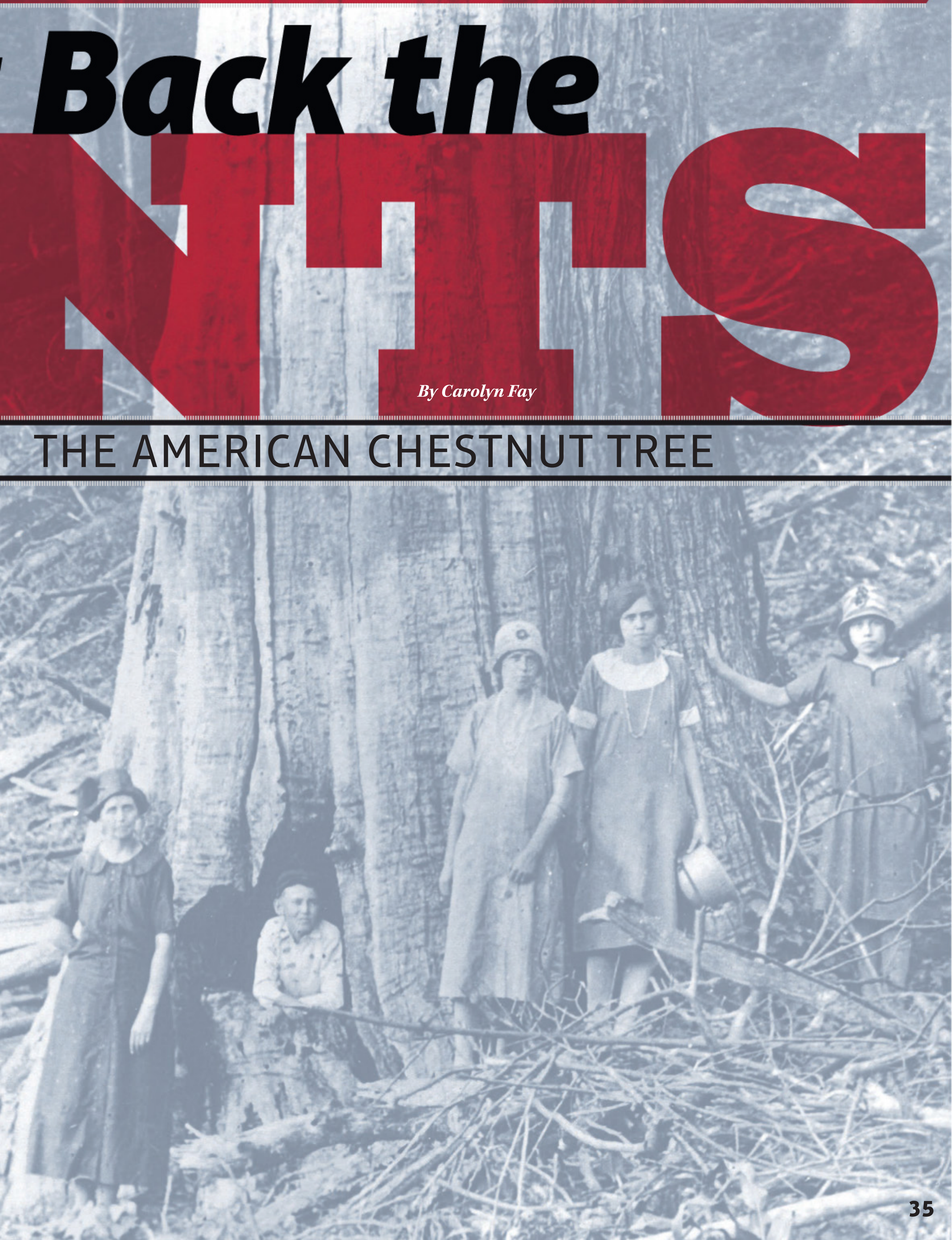
How could a fungus kill so many trees? *Cryphonectria parasitica* is not native to North America. It likely came to the US as a stowaway on imported Japanese chestnut trees. Japanese and Chinese chestnut trees often survive the blight. Scientists call this "blight resistance." Because Asian chestnuts evolved alongside of *Cryphonectria parasitica*, they had thousands of years to adapt to it. When the fungus invaded the bark of one of Merkel's trees—likely through an animal's scratch or an insect's burrowing—the American chestnut had no defense.

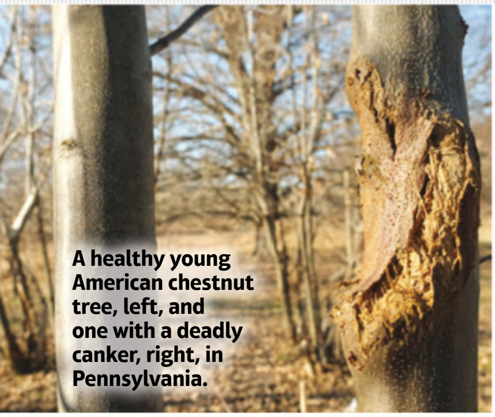
The blight doesn't attack the American chestnut tree's roots, so sprouts do spring up around dead stumps. But when these sprouts grow into saplings, the blight

Back the NTS

By Carolyn Fay

THE AMERICAN CHESTNUT TREE





A healthy young American chestnut tree, left, and one with a deadly canker, right, in Pennsylvania.

A Large Surviving American chestnut tree, or LSA, stands tall today in Kentucky.

strikes, like a predator lying in wait. Dan O'Keefe is vice president of the Pennsylvania/New Jersey chapter of The American Chestnut Foundation (TACF). He says American chestnut trees are "functionally extinct." They can't mature and reproduce normally, but they haven't completely disappeared.

American chestnut scientists are persistent, too. They are working to restore the giants using a combination of traditional and cutting-edge methods. The American Chestnut Foundation calls this work 3BUR. That stands for *Breeding*, *Biotechnology*, and *Biocontrol United for Restoration*.

Burs and nuts from a hybrid chestnut tree, or "chestmutt"

Blight-Fighting Chestmutts

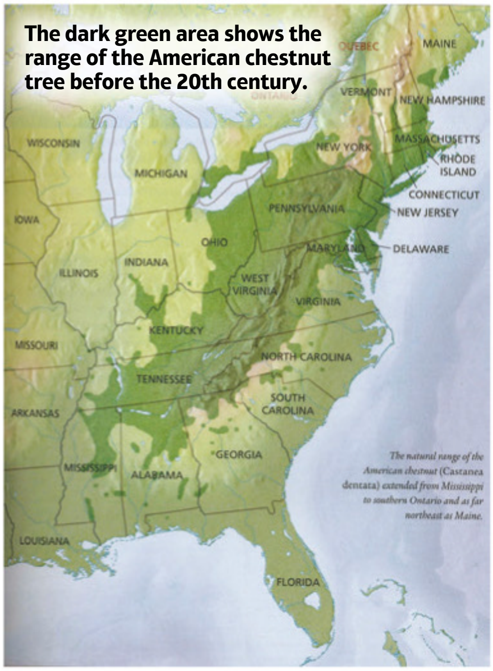
O'Keefe also leads the American chestnut volunteers at Tyler Arboretum outside Philadelphia, Pennsylvania. Here, they care for an American chestnut *germplasm* orchard. The word *germplasm* refers to genetic material. Orchards like this one contain a representative sample of wild American chestnut trees from various regions. They help TACF's breeding program create trees that resemble the American chestnut but are able to resist blight. Volunteers at Tyler harvest, shuck, and count nuts. In the fall, they send 3,000 to 4,000 nuts to TACF.

Other TACF orchards focus on crossing American chestnut trees with Chinese chestnuts. Scientists hope their offspring will inherit the Chinese blight-fighting superpower. TACF Chief Conservation Officer Sara Fitzsimmons calls these "chestmutts." That's because genetic analysis shows they have varying amounts of American, Asian, and even European DNA. Most of the chestmutts don't resist the blight that well. Scientists recently discovered the Chinese chestnut's blight resistance is complicated. It involves at least a dozen genes, more than most chestmutts are inheriting from their parents.

Send in the Clones!

A few wild American chestnuts manage to survive long enough to flower despite the blight. Fitzsimmons, though, says they look terrible, with "cruddy bark." Chestnut scientists call them "LSAs"—or "Large Surviving Americans." Fitzsimmons likens them to wounded soldiers. These valiant trees are the latest weapon in the breeding program.

Using a technique called *grafting*, breeders take a twig from an LSA and attach it to a compatible root system of another chestnut. The new tree will be a copy, or clone, of the original tree from the twig. "We want multiple copies so we can preserve it and study it in different ways," Fitzsimmons says. By studying the clones' genomes, scientists hope to determine which genes participate in their blight resistance. The LSA-clones and the chestmutts will factor in the second restoration "B": biotech.



The dark green area shows the range of the American chestnut tree before the 20th century.

The natural range of the American chestnut (Castanea dentata) *extended from Mississippi to southern Ontario and as far northeast as Maine.*

Researchers tend to a young, blight-resistant transgenic American chestnut tree.

A volunteer plants hybrid chestnut seeds in Maryland.

Spring planting at the State University of New York (SUNY) includes transgenic American chestnut trees.

Secret Weapon

Experts in biotechnology at the State University of New York (SUNY) had an intriguing idea. Could they take a blight-resistant gene from another plant and insert it into the American chestnut's DNA? This would create a genetically modified or "transgenic" American chestnut. It would be like arming the tree with a secret weapon. *Cryphonectria parasitica* destroys tree cells using oxalic acid. The team found a wheat gene that converts oxalic acid into harmless hydrogen peroxide and carbon dioxide. This gene is called OxO.

How scientists transfer this secret weapon is clever. Researcher Linda McGuigan helped develop the process. She opens nuts from immature American chestnuts, removes the embryos, and grows them on a nutrient-filled medium. After the embryos multiply, McGuigan applies *Agrobacterium. Agrobacterium* is a microbe that lives in the soil near the roots of plants. McGuigan calls it a "natural genetic engineer."

Agrobacterium is sneaky—it attaches to plants and transfers over some of its DNA. This fools plants into making food for the bacterium. Scientists can be sneaky, too. They disarm the *Agrobacterium* so that instead of transferring its own gene, it transfers the OxO gene.

Tests in SUNY's orchards show the transgenic chestnut trees do resist the blight. The next step will be to breed them with chestmutts and LSA-clones to diversify them. It's currently illegal, though, to plant transgenic trees outside of test plots. US regulators are reviewing a petition to approve the transgenic American chestnut for public planting. There's a lot to learn about how they might impact the environment.

Eventually, *Cryphonectria parasitica* may adapt and overcome the transgenics' secret weapon. That's why restorers aren't putting all their chestnuts in one basket. The third "B"—*biocontrol*—takes the fight directly to the blight.

Fungus Vs. Virus

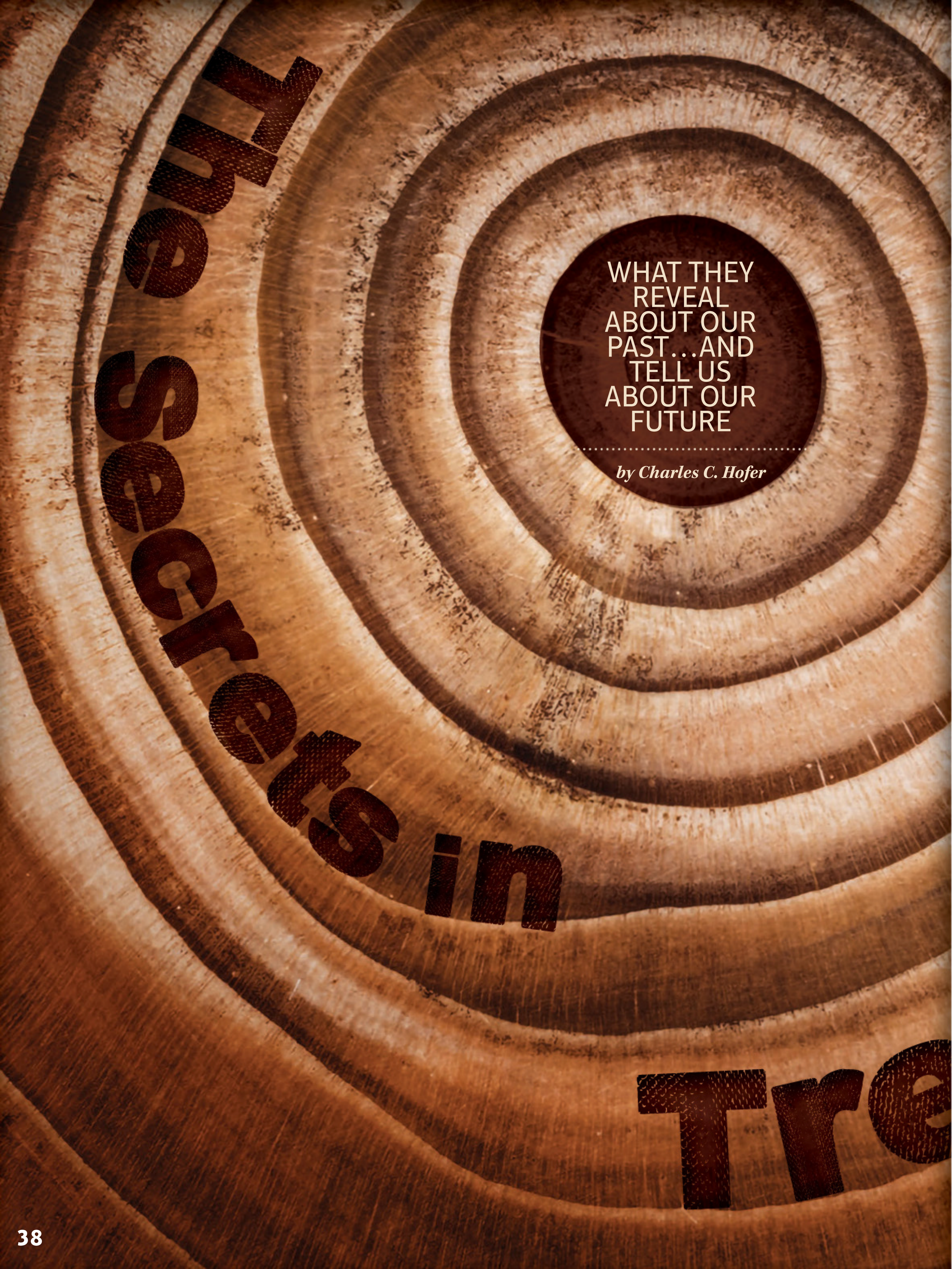
Scientists in the 1950s noticed some European chestnuts in Italy were surviving the blight. Except instead of the usual reddish-orange, the *Cryphonectria parasitica* appeared white. It grew more slowly, too. Matt Kasson is a forest pathologist at West Virginia University. "Plants get sick. Fungi can get sick, too," he says. The blight fungus was infected with a virus! This discovery inspired the idea of biocontrol. Instead of changing the American chestnut, scientists could weaken the blight.

Infecting the blight with the virus can be tricky. One problem, Kasson explains, is how fungi "catch" viruses. "It's not like the fungi out there are coughing, spreading the virus particles," he says. A fungal strain will share a virus with another only if they are compatible. To help spread the virus, scientists genetically engineered a fungus called Super Donor 1.0. When it meets a wild strain of the blight, Super Donor always shares the virus. It's like a germy relative who gets everyone sick at a party.

Kasson and his colleagues get the party started by punching holes around the canker of a blight-infected tree and slathering on the Super Donor. Results from the first test were promising. Ninety-four percent of treated cankers caught the virus. But trees will need repeated doses to keep the blight at bay. Super Donor's greatest usefulness may be at germplasm orchards like the one at Tyler Arboretum. "Super Donor will allow the trees to have a fighting chance when they get natural infections," Kasson says.

A fighting chance is exactly what scientists want for the American chestnut. Fitzsimmons notes, though, that "the restoration of a tree species is beyond any of our lifetimes." Chestnuts grow slowly. There will be plenty of work for future generations.

Carolyn Fay now figures the roasted chestnuts she ate on a street corner in New York City when she was a kid in the 1980s were probably Italian chestnuts. She hopes one day to try an American chestnut. She hears they taste carroty.



The Secrets in Tre

WHAT THEY REVEAL ABOUT OUR PAST…AND TELL US ABOUT OUR FUTURE

by Charles C. Hofer

e Rings

The high desert of northwest New Mexico is a windswept and endless landscape of rolling red hills and dramatic rock formations. These are ancient lands, home to some of the oldest civilizations in North America. For millennia, the Puebloan people thrived in this desert environment. They constructed massive settlements, built from mud and stone and supported by wood gathered from the surrounding mountain forests.

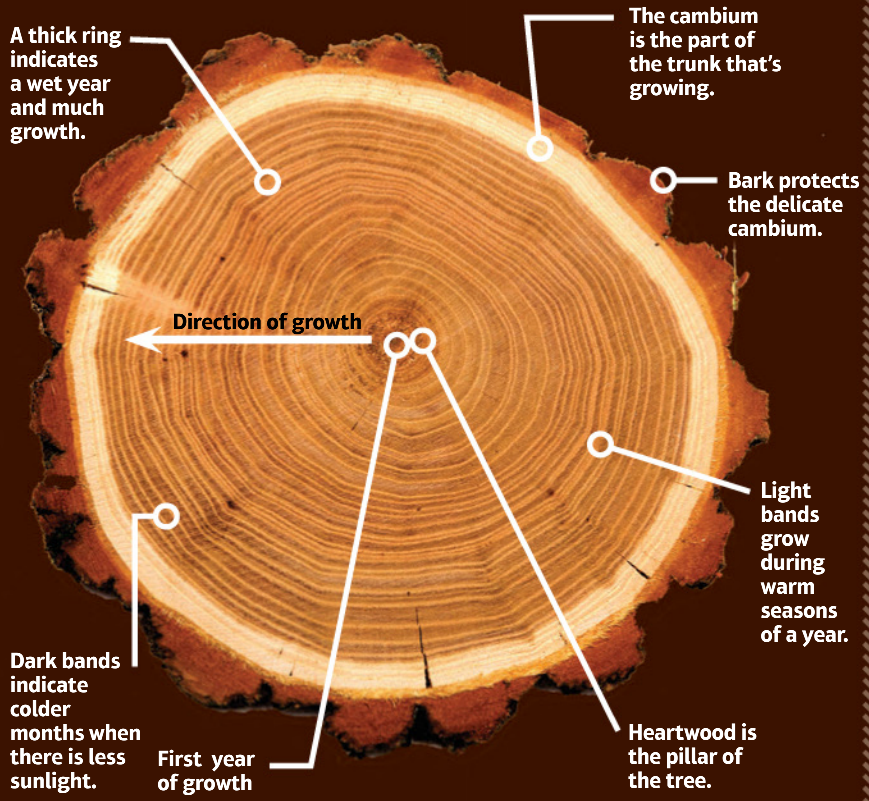
In Chaco Canyon stands the ruins of one of these settlements. Pueblo Bonito was a sprawling building that stood five stories tall and contained more than 600 rooms. At its peak around 1080 CE, Pueblo Bonito may have housed up to 1,000 people in a kind of ancient apartment complex.

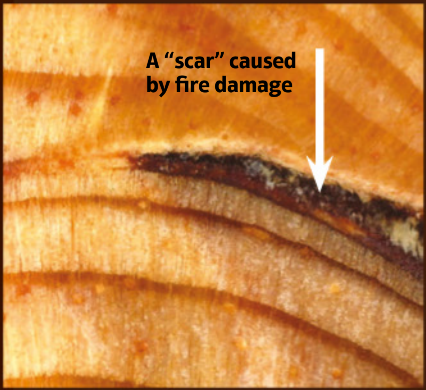
For hundreds of years, Pueblo Bonito marked the cultural epicenter of the Desert Southwest. Then, the Puebloans disappeared. By the 14th century, Pueblo Bonito was abandoned. To this day, nobody knows why.

But the Puebloans left clues behind. They are in the wooden beams of Pueblo Bonito. They're locked away in wooden ladders and old fire wood. The answers to why Puebloans left are hidden in tree rings.

text © 2023 by Charles C. Hofer

TREE CROSS SECTION


A thick ring indicates a wet year and much growth.
The cambium is the part of the trunk that's growing.
Bark protects the delicate cambium.
Direction of growth
Light bands grow during warm seasons of a year.
Dark bands indicate colder months when there is less sunlight.
First year of growth
Heartwood is the pillar of the tree.


A "scar" caused by fire damage

The Art of Tree Rings

Cut a cross section of a tree and you'll see lines and lines circling each other. These patterns capture the history of the tree. Tree rings tell stories of life and death. They tell stories of wet years when there was plenty of food to eat. They tell stories of dry years when water was scarce. Tree rings tell the stories of when civilizations flourished and when they collapsed.

Dendrochronology is the science of dating things—events, climate, artifacts—by examining the annual growth patterns found in tree rings. Dendrochronologists study the tree rings of certain species of trees to piece together the history of the environment.

Each year, a tree adds rings to its *cambium*. This is the layer of woody cells, called ***new wood***, found just below the bark. During the warmer, sunny seasons, a tree adds growth that appears as a light ring. This is called *early wood*. During the colder months when there is less sunlight, a tree adds a thinner, darker ring. This is called *late wood*. A pair of new wood and late wood represents one year.

For dendrochronologists, the rings hold clues. Thick rings indicate a lot of growth, suggesting a wet year and a favorable environment. Thin rings tell of lean years when it was dry. The types of oxygen atoms in the wood cells reflect the origin of water and humidity. The types of carbon atoms trapped in the wood can suggest photosynthetic rates, amount of soil moisture, and the level of sunlight. Each clue is another indicator of feast or famine.

Tree rings can also reveal specific events that might have rapidly altered an environment. When a wildfire burns a tree's cambium, the tree doesn't grow. What's left behind is a scar, like a bookmark hidden in the rings of time. Disease, earthquakes, and volcanic eruptions also leave marks showing when a tree struggled to survive. These catastrophic events could even provide clues about the rise and fall of ancient societies living nearby.

"When food resources are threatened from drought, disease, war, flooding, etc., it can be disastrous for a society," says Tom Windes. He's an archeologist and dendrochronologist who worked in Chaco Canyon for decades. "For agricultural societies, especially, which are dominant for much of

Looking for clues to a tree's life

Pueblo Bonito in northwest New Mexico features ancient houses and *kivas*, or meeting rooms, that were built from stone, mud, and wood.

human life, [tree rings] can tell us when good and bad years happened and their probable effect on those societies dependent on agriculture."

An Ancient Mystery

Today, Pueblo Bonito is preserved at the Chaco Culture National Historical Park in New Mexico. At the park, the mystery endures: Why did the Puebloans suddenly abandon Pueblo Bonito?

Evidence from tree rings suggests that Pueblo Bonito flourished from about 800 CE to about 1080 CE. As the wood used in the settlement was all harvested in the same region, scientists can use crossdating to create a calendar of when the wood was harvested. These data tell the story of a growing settlement, adding rooms and buildings to Pueblo Bonito over the decades. For example, wood used in one room might date back to 950 CE, while wood in another room dates to 1000 CE. This indicates builders must have been expanding the structure.

Wood found at Pueblo Bonito provides other clues, too. The nearby area is relatively tree-less, yet the

CROSSDATING

Tree rings tell scientists about the environment over the period of a tree's life. But if a tree only lives a couple hundred years, how does a dendrochronologist piece together the story of the environment from thousands of years ago?

Crossdating is the process of comparing the patterns of tree rings. Using an instrument like a corkscrew called a borer, a dendrologist can extract a core from a tree. The rings found in a core resemble a unique barcode, creating a pattern of lines and spaces. Patterns from one tree core will overlap with other trees from the same area. With enough well-preserved trees, a dendrochronologist can piece together the climate over centuries.

Twist your narrow, hollow borer—about the size of a straw—into a tree trunk...

Pop out a long core sample of wood...

Return to the lab for measurements and compare to other trees!

Core samples let dendrochronologists view tree rings without seriously harming trees.

At Pueblo Bonito, researchers examine everything from ancient beams to stone walls that were once part of buildings that stood five stories tall.

buildings used tens of thousands of pieces of wood. Where did it all come from?

Dendrochronologists compared tree rings at Pueblo Bonito with trees from surrounding forests. Similarities in tree rings suggested that the wood was harvested from mountain forests up to 50 miles (80 km) away. This was a monumental feat for an ancient culture. Harvesting this wood, however, might have also contributed to the Puebloan's ultimate fate.

To create Pueblo Bonito, the Puebloans used pinyon pine and juniper. These hardwoods are great for building structures, but they're slow growing. As Pueblo Bonito expanded, the Puebloans needed more wood. Over time, they might have over-exploited the resource. Trees became scarce.

Left to History

What compelled the Puebloans to eventually abandon their massive settlement? Tree ring data revealed that massive environmental changes might have forced the Puebloans from Chaco Canyon.

Using 1,845 tree ring chronologies, scientists reconstructed the climate of North America from the year 0 CE to 2005 CE. The result was the *North American Drought Atlas*. This exhaustive study revealed that about the time Pueblo Bonito was abandoned, the region was suffering from a megadrought that lasted decades.

The Puebloans most likely found life in Chaco Canyon unsustainable during the megadrought. Times were lean for the people of the Desert Southwest. Water was scarce. Resources were depleted. The time had come to move on, closer to water sources and other resources. Windes explains, "The Puebloan peoples migrated south to numerous places after leaving the Four Corners, including the Rio Grande Valley and its tributaries."

Tree Rings and Our Future

While dendrochronology helps piece together the past, the science is also helping land managers prepare for a challenging future. For example, wildfires are a growing risk in the western United States. Tree rings can tell the history of major wildfires across the landscape by revealing how forests recovered from these events. This information can help forest managers take actions to protect forests as the climate warms.

Tree ring data can also help water resources managers better prepare for periods of drought. Tree rings hold the history of river flows, demonstrating how trees adapt to periods of low water.

Dendrochronology is also helping scientists understand how our current climate measures up with ancient history. It doesn't look good. Tree ring studies show that the climate has warmed considerably beginning in the early 1900s—about the same time humankind greatly increased its reliance on fossil fuels. These studies even suggest that future megadroughts could eclipse the one that ultimately doomed Pueblo Bonito.

"Tree rings highlight the sudden… growing problem of climate change that is beyond anything we have seen in records going back 400,000 years," says Windes. "These records alert us that this unprecedented change will continue to grow grimmer without desperate changes in our behavior of polluting the earth's atmosphere, waters, and lands."

There's no doubt our global climate is warming. Fresh water levels around the world are dropping as sea levels rise. Wildfires are getting bigger and more destructive. It's a perfect storm for an unsustainable world. If the trees hold the secrets of our past, they just might help us prepare for our future, too.

Charles C. Hofer is a writer and biologist living in New Mexico, not far from Chaco Canyon. If you crossdated him, you'd find he's about as old as the Endangered Species Act.

BY SARAH GOTTLIEB AND KATHRYN HULICK

DroneSeed drones can spread tree seeds much faster than people can on their own.

COULD DRONE TECHNOLOGY RAPIDLY REPLANT FORESTS AFTER WILDFIRES?

HEALTHY FORESTS PROVIDE HABITATS FOR WILDLIFE, KEEP OUR AIR AND WATER CLEAN, AND HELP SLOW DOWN CLIMATE CHANGE. Wildfires are a normal part of many forest life cycles, but the number and severity of fires are increasing. Forest fires today burn twice as many trees as they did 20 years ago.

What should we do to help forests recover? People can plant new trees, but this is a huge and dangerous task. Imagine carrying a sack of seedlings on your back and walking for hours back and forth across a steep mountainside. One person can only plant about two to three acres (one hectare) a day.

Could drones do the job instead? DroneSeed, a company based in Seattle, Washington, uses drones to both map the burned terrain and plant trees. First, a small, nimble "recon drone" flies out over the territory. It creates a map of the landscape that reveals which areas are ideal for planting. Roads, rivers, and rocky areas are labeled as "no-plant zones."

This planting map is then uploaded to large "seeding drones." Each one stretches about six feet (1.8 m) across. "They weigh quite a lot," says DroneSeed scientist Ehren Moler.

Three to five seeding drones fly out at the same time in a group or "swarm." Watching them fly over a burned landscape looks like a scene from a sci-fi movie. They each drop hundreds of "seed pucks" according to the map. Each one looks a bit like a hockey puck made of dirt. It contains seeds, fertilizer, and protective materials. There may also be a dash of cayenne pepper or a clump of steel wool so that rodents don't snack on the seeds.

These drones can cover 20 to 40 acres (eight to 16 hectares) a day, according to DroneSeed. It would take about 15 people to complete the same task. Also, the drones can get to work soon after a wildfire, when the ground is still unsafe for people to walk on.

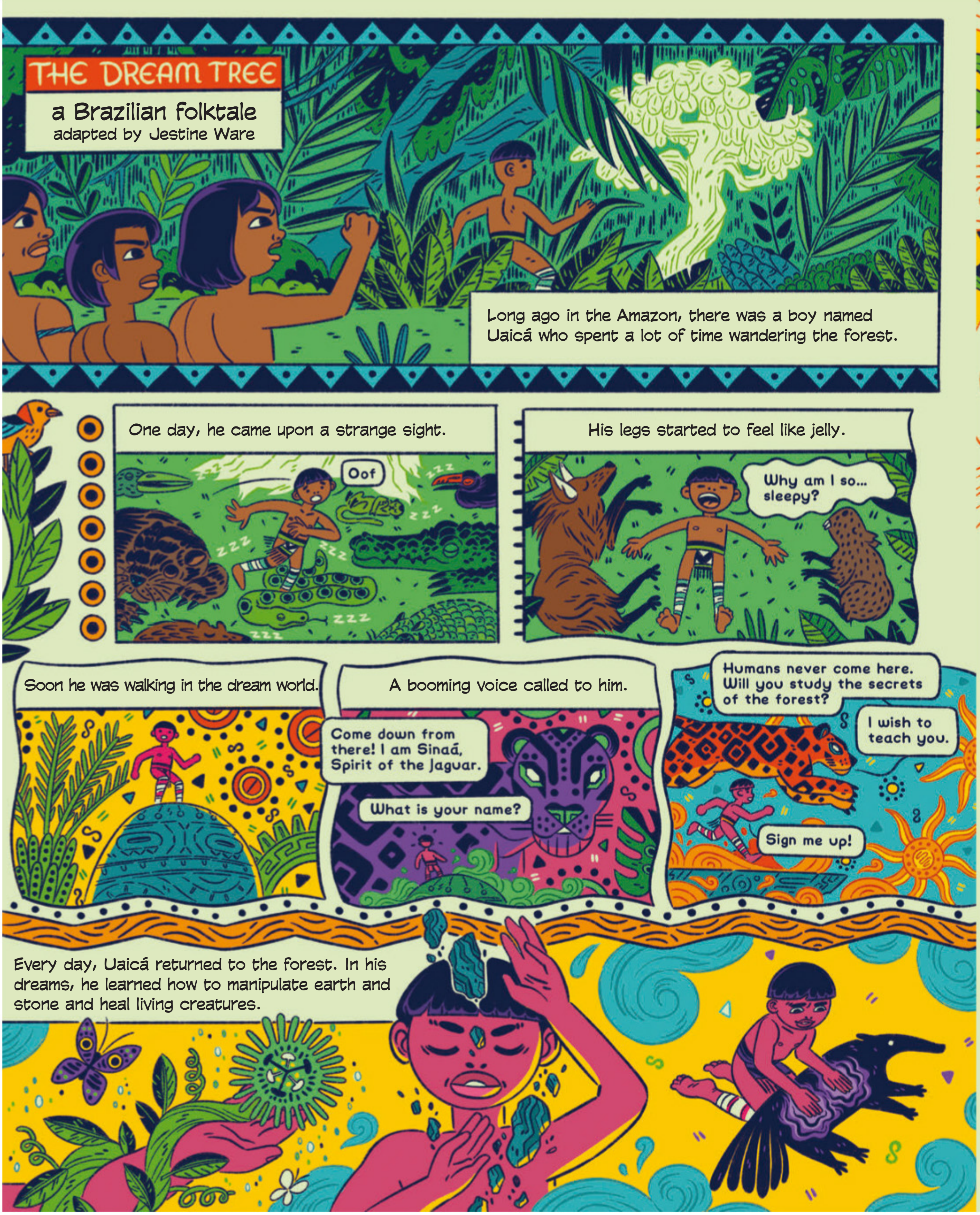
This all sounds great, but what if people see quick-and-easy drone replanting as an excuse to cut down trees? Others might turn to tree-planting as a reason to not take other steps to curb climate change.

And replanting trees doesn't always work. According to one study, less than 20 percent of the seeds that drones drop actually grow into trees. Also, they're not always the right types of trees for an area. Once the right kinds of trees have been planted, they must be protected over many decades from fire as well as logging and other threats.

What do you think? Should we send out the drones? What else can we do to keep forests healthy?

Sarah Gottlieb is a writer living in Los Angeles, California, with her family. They're on their second drone and fourth remote control (RC) helicopter. They've found that both are easy to fly and hard to land!

Kathryn Hulick loves everything about gardening. She'd much rather put a tree in the dirt by hand than use a drone. She lives in Massachusetts with her family.

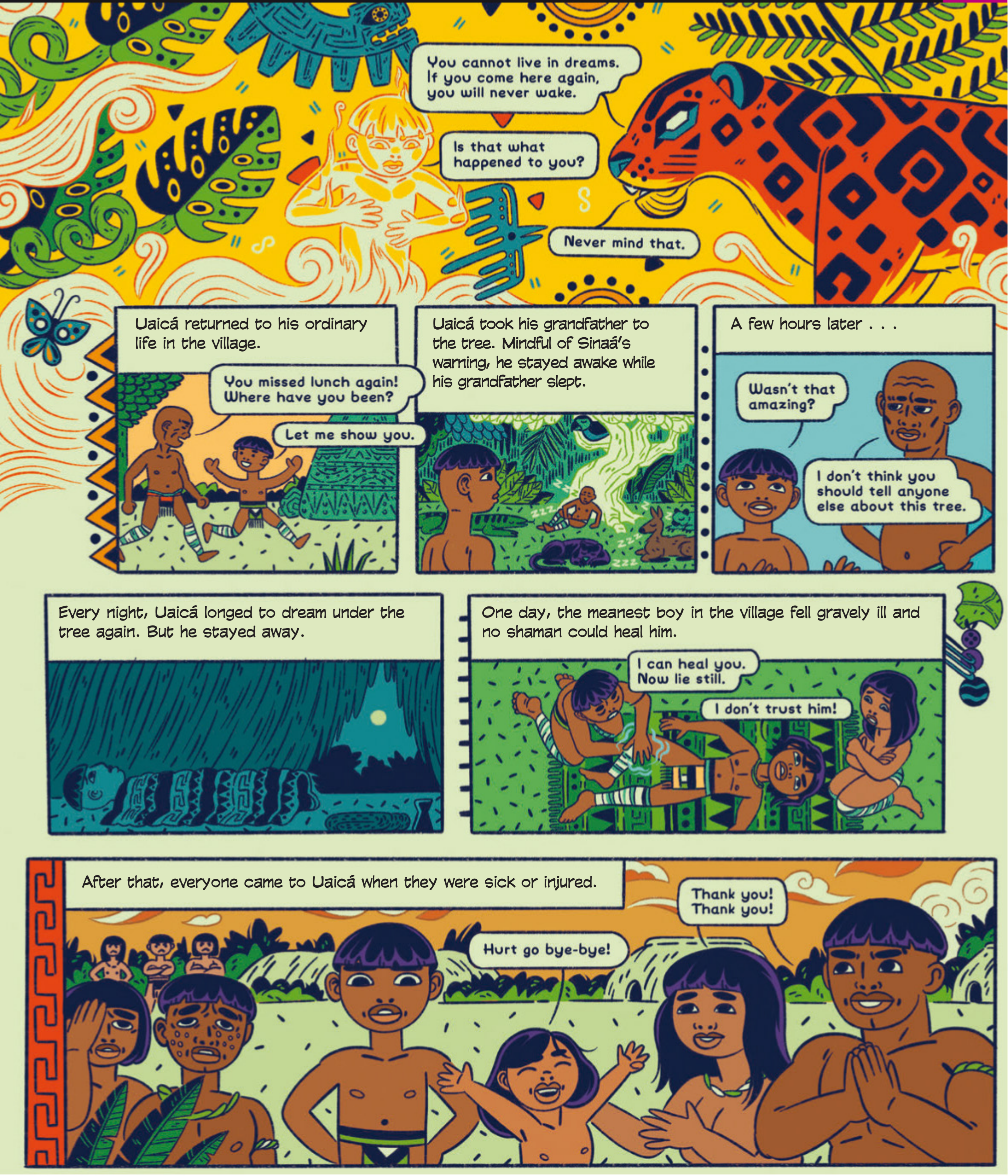


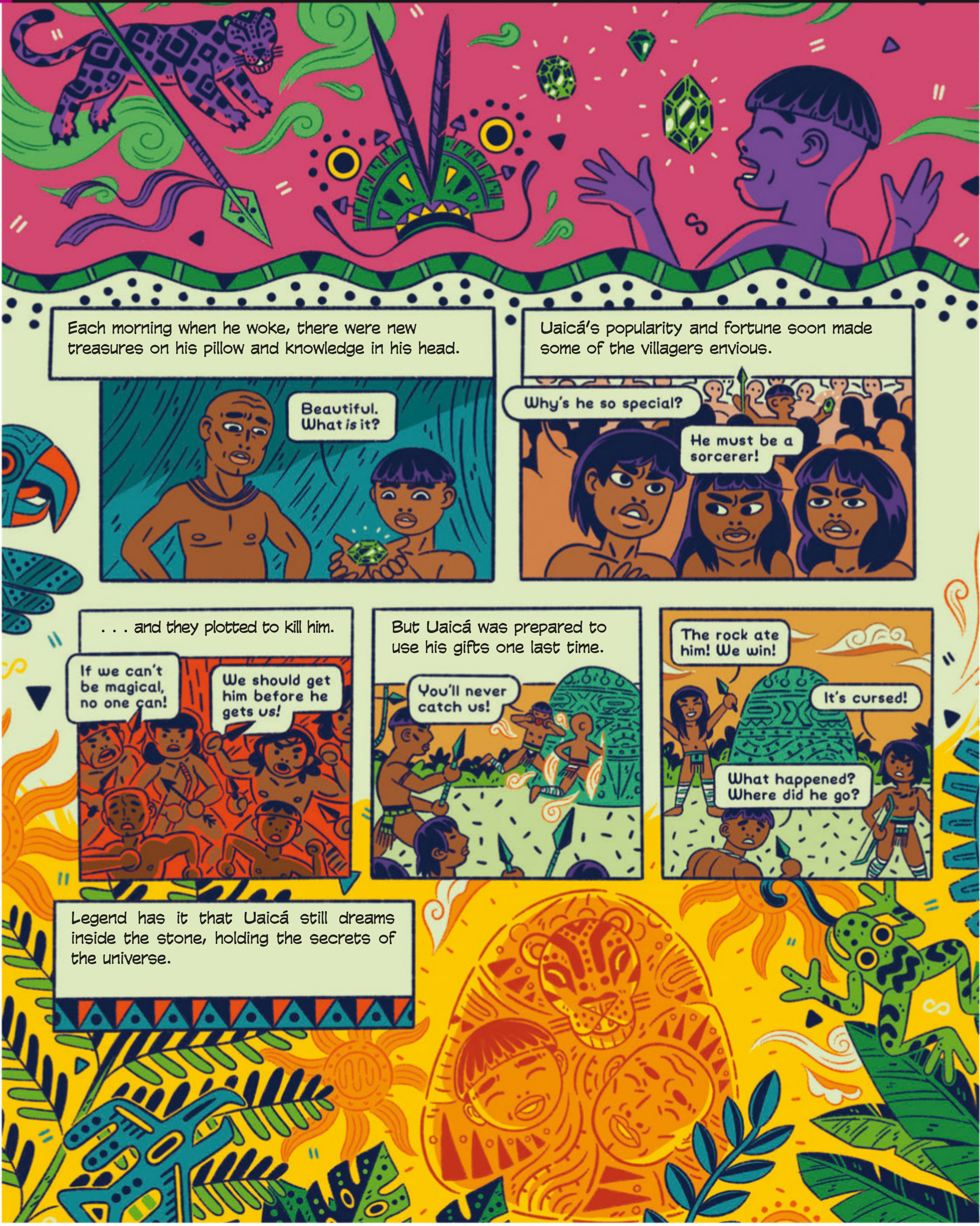
THE DREAM TREE

a Brazilian folktale

adapted by Jestine Ware

Long ago in the Amazon, there was a boy named Uaicá who spent a lot of time wandering the forest.
One day, he came upon a strange sight.
Oof
His legs started to feel like jelly.
Why am I so... sleepy?
Soon he was walking in the dream world.
A booming voice called to him.
Come down from there! I am Sinaá, Spirit of the Jaguar.
What is your name?
Humans never come here. Will you study the secrets of the forest?
I wish to teach you.
Sign me up!
Every day, Uaicá returned to the forest. In his dreams, he learned how to manipulate earth and stone and heal living creatures.


You cannot live in dreams. If you come here again, you will never wake.
Is that what happened to you?
Never mind that.
Uaicá returned to his ordinary life in the village.
You missed lunch again! Where have you been?
Let me show you.
Uaicá took his grandfather to the tree. Mindful of Sinaá's warning, he stayed awake while his grandfather slept.
A few hours later . . .
Wasn't that amazing?
I don't think you should tell anyone else about this tree.
Every night, Uaicá longed to dream under the tree again. But he stayed away.
One day, the meanest boy in the village fell gravely ill and no shaman could heal him.
I can heal you. Now lie still.
I don't trust him!
After that, everyone came to Uaicá when they were sick or injured.
Thank you! Thank you!
Hurt go bye-bye!



Each morning when he woke, there were new treasures on his pillow and knowledge in his head.

Beautiful. What *is* it?

Uaicá's popularity and fortune soon made some of the villagers envious.

Why's he so special?
He must be a sorcerer!

. . . and they plotted to kill him.

If we can't be magical, no one can!
We should get him before he gets us!

But Uaicá was prepared to use his gifts one last time.

You'll never catch us!

The rock ate him! We win!
It's cursed!
What happened? Where did he go?

Legend has it that Uaicá still dreams inside the stone, holding the secrets of the universe.

>> NEW CONTEST

New Contest: Treehouse Hideaway

Who doesn't want to get off the ground from time to time? The real action happens among birds, branches, and leaves. If you moved up into the treetops, where would you live? Design your dream treehouse, outfitted with everything you need to make the move. Sketch it, paint it, or build a miniature model and photograph it. No matter the method, send us an image of your creation, and we'll fill a forest canopy of dwellings from our perch.

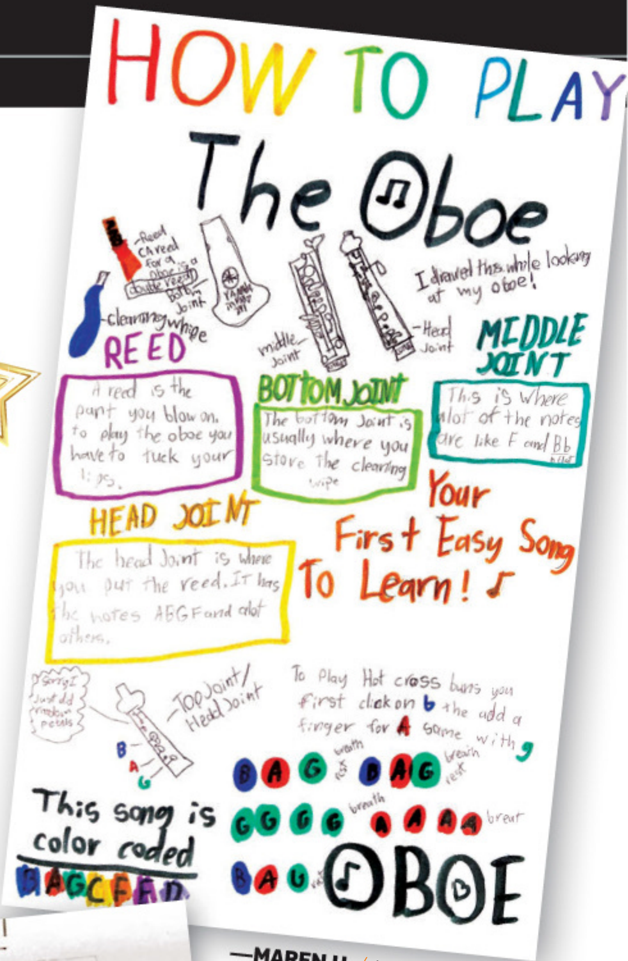
CONTEST RULES

1. Your contest entry must be your very own original work. Ideas and words should not be copied.
2. Be sure to include your name, age, and full address on your entry.
3. Only one entry per person, please.
4. If you want your work returned, enclose a self-addressed, stamped envelope.
5. All entries must be signed by a parent or legal guardian, saying that this is your own work and no help was given and granting permission to publish. For detailed information about our compliance with the Children's Online Privacy Protection Act, visit the policy page at cricketmedia.com/privacy.
6. Your entry must be received by May 1, 2023. We will publish winning entries in the October 2023 issue of *Muse*.
7. Send entries to Muse Contest, 1 East Erie Street, Suite 525, PMB4136, Chicago, IL 60611 or via email to muse@cricketmedia.com. If entering a digital photo or scan, please send at 300 dpi.

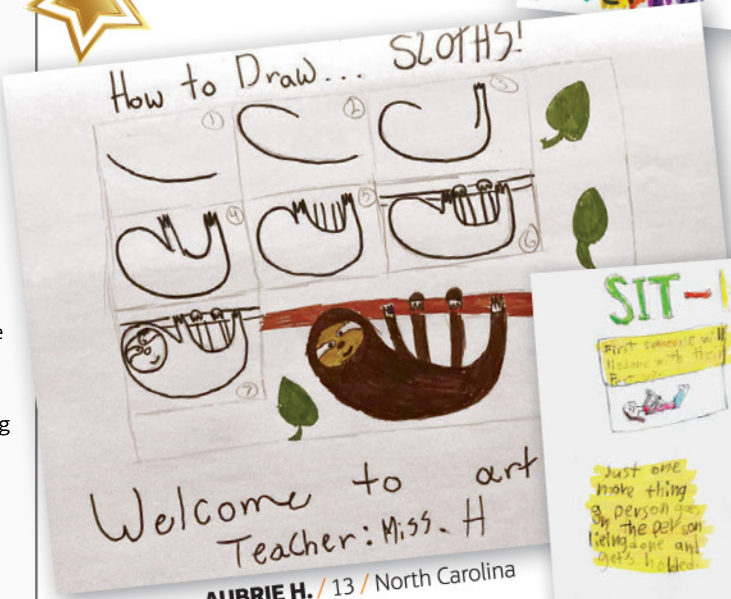
>> ANNOUNCING

CONTEST WINNERS!

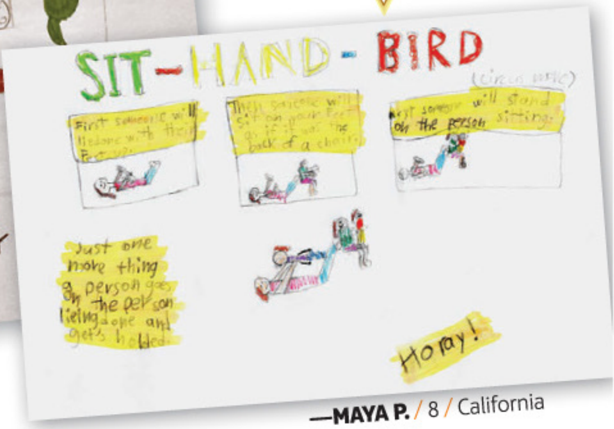
In November, you took control of the class to lead a lengthy lecture on a lesson you love and want to share. We learned so much from you wise teachers. Now class, pay attention! After all, who better to learn from than a fellow Muser?


HOW TO PLAY
The Oboe
-Reed (A reed for a oboe is a double reed)
Bottom Joint
-clearing whipe
I drawed this while looking at my oboe!
middle Joint
-Head Joint
REED
A reed is the part you blow on. to play the oboe you have to tuck your lips.
BOTTOM JOINT
The bottom Joint is usually where you store the clearing wipe
MIDDLE JOINT
This is where alot of the notes are like F and Bb
HEAD JOINT
The head Joint is where you put the reed. It has the notes ABGF and alot others.
Your First Easy Song To Learn!
Sorry I Just did random petals
-Top Joint/ Head Joint
B A G
To Play Hot cross buns you first click on b the add a finger for A same with g
B A G breath rest B A G breath rest
G G G G breath A A A A breath
B A G
This song is color coded
B A G C F F D
OBOE

—**MAREN H.** / 10 / Minnesota


How to Draw... SLOTHS!
1
2
3
4
5
6
7
Welcome to art
Teacher: Miss. H

—**AUBRIE H.** / 13 / North Carolina


SIT-HAND-BIRD
(circus style)
First someone will lie down with their feet up.
Then someone will sit on your feet as if it was the back of a chair.
next someone will stand on the person sitting.
Just one more thing a person goes on the person lieing done and get's holded.
Horay!

—**MAYA P.** / 8 / California

>> ANSWERS

PAGES 6-9 MUSE NEWS

The false story is "Ventriloquism for Dummies."

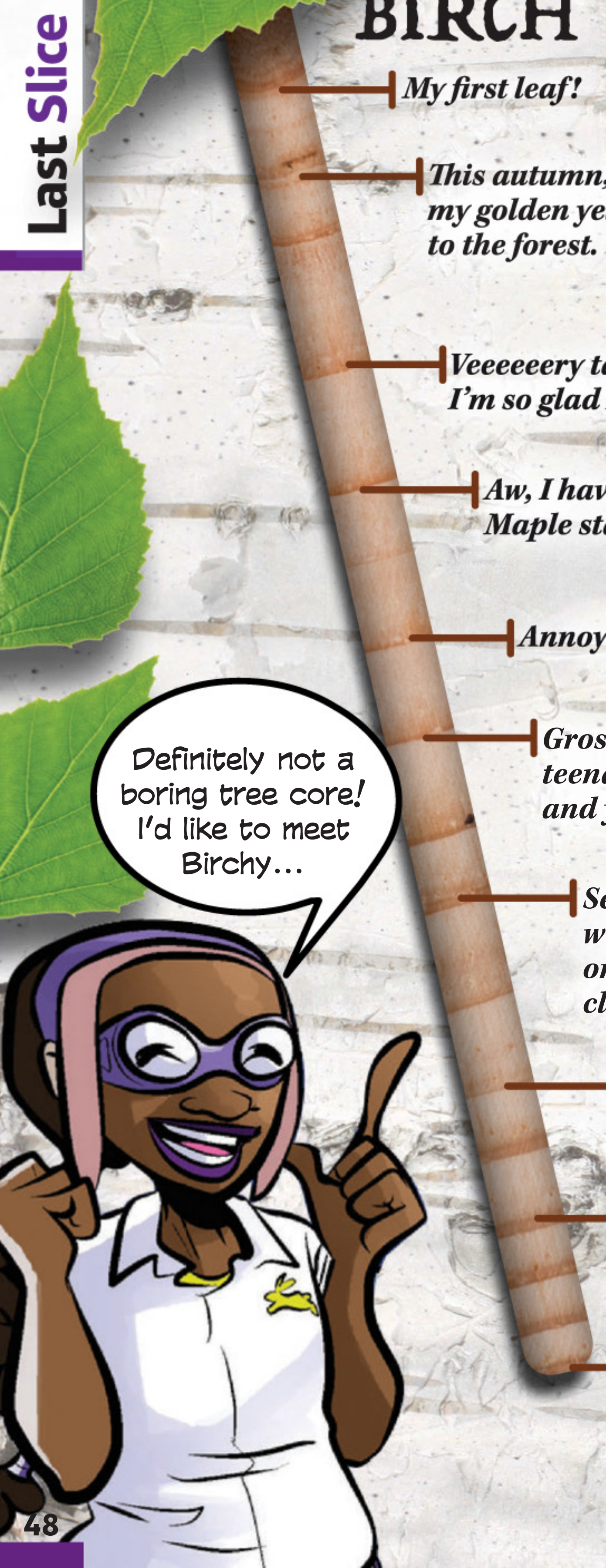
>> RUNNERS-UP

Honorable Mention

This month's runners-up are Eliza W., 13, West Virginia; Evelyn M., 10, California; Henry C., 10, North Carolina; Lydia P., 11, Nebraska; Maximillian V., 10, New York; Olivia W., 11; Simeon P., 8, Nebraska.

BY EMILY CAMBIAS

DIARY OF A BIRCH TREE


Definitely not a boring tree core! I'd like to meet Birchy...

My first leaf!

This autumn, I showed off my golden yellow leaves to the forest.

Veeeeeery tasty rain this year. I'm so glad I grow near a creek.

Aw, I have a new neighbor nearby. Maple starts growing.

Annoying woodpecker moves in. Ugh.

Gross fungus infects a branch. Luckily, a teenager wearing a reflective vest comes by and yanks off the branch. Ahh, much better.

Serious windstorm. I worry for a minute I won't be standing afterward. I don't mind once things have calmed down again... cleaned out a few bad twigs and some leaves.

Maple starts growing a little close. Stay in your own mulch!

The woodpecker comes for us both. Maple and I commiserate over the noise. The bright red tree isn't so bad after all.

Weird guy drills a bit out of my trunk. He's quicker than the woodpecker, I'll give him that. He doesn't appear to be after my sap, thank goodness. I wonder what he needs it for....

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lǎo shī
老师
小狗
The Little Dog
Spider

Cricket

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> “My discovery was that mycorrhizae actually connect many trees in a forest—even trees of different species and ages. **What’s even more remarkable is that trees share with one another through this vast underground fungal network.**”